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Issued December 30, 1910.

U. S. DEPARTMENT OF AGRICULTURE

OFFICE OF EXPERIMENT STATIONS—BULLETIN 229.

A. C. TRUE, Director.

DELIVERY OF WATER TO IRRIGATORS.

BY

FRANK ADAMS,

Irrigation Manager, in Charge of Work in California.

PREPARED UNDER THE DIRECTION OF

SAMUEL FORTIER,

Chief of Irrigation Investigations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION.

NOTE.—Publications marked with an asterisk (*) are not available for distribution.

BULLETINS.

*Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64.

*Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80.

*Bul. 60. Abstract of Laws for Acquiring Titles to Water from the Missouri River and its Tributaries, with the Legal Forms in Use. Compiled by Elwood Mead. Pp. 77.

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*Bul. 130. Egyptian Irrigation. By Clarence T. Johnston. Pp. 100.

*Bul. 131. Plans of Structures in Use on Irrigation Canals in the United States, from drawings exhibited by the Office of Experiment Stations at Paris, in 1900, and at Buffalo, in 1901, prepared under the direction of Elwood Mead, Chief. Pp. 51.

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*Bul. 181. Mechanical Tests of Pumping Plants in California. By J. N. Le Conte. Pp. 72.

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OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Director.
E. W. ALLEN, Assistant Director.

IRRIGATION INVESTIGATIONS.

SAMUEL FORTIER, Chief.
R. P. TEELE, Assistant Chief.

IRRIGATION ENGINEERS AND IRRIGATION MANAGERS.

A. P. STOVER, Irrigation Engineer, in charge of work in Oregon.

C. E. TAIT, Irrigation Engineer, in charge of work in southern California.

S. O. JAYNE, Irrigation Manager, in charge of work in Washington.

FRANK ADAMS, Irrigation Manager, in charge of work in California.

W. W. McLAUGHLIN, Irrigation Engineer, in charge of work in Utah.

P. E. FULLER, Irrigation Engineer, in charge of work in Arizona and of power investigations.

W. L. ROCKWELL, Irrigation Manager, in charge of work in Texas.

D. H. BARK, Irrigation Engineer, in charge of work in Idaho.

MILO B. WILLIAMS, Irrigation Engineer, in charge of work in humid sections.

V. M. CONE, Irrigation Engineer, in charge of work in central California.

C. G. HASKELL, Irrigation Engineer, in charge of rice investigations.

FRED G. HARDEN, Scientific Assistant.

R. D. ROBERTSON, Assistant Irrigation Engineer.

J. W. LONGSTRETH, in charge of work in Kansas.

COLLABORATORS.

O. V. P. STOUT, University of Nebraska, in charge of work in Nebraska.

GORDON H. TRUE, University of Nevada, in charge of work in Nevada.

W. B. GREGORY, Tulane University of Louisiana, in charge of rice irrigation in Louisiana and Texas.

F. L. BIXBY, New Mexico Agricultural College, in charge of work in New Mexico.

IRRIGATION FARMERS.

JOHN H. GORDON, R. G. HEMPHILL, W. H. LAUCK, R. E. MAHONEY, and JOHN KRALL, Jr.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., April 30, 1910.

Sir: I have the honor to transmit herewith a report on the delivery of water to irrigators, prepared by Frank Adams under the direction of Samuel Fortier, chief of irrigation investigations. The successful operation of an irrigation enterprise depends very largely upon the system adopted for distributing water to the irrigators. No single factor adds more to the chances of success for both the canal owners and the farmers than an assurance that water will be delivered when it is due. In this report Mr. Adams describes the systems adopted on some forty or fifty irrigation enterprises throughout the West, in the hope that the description will lead to the more general adoption of efficient systems of distribution, that it will impress irrigators and irrigation managers with the value of measuring the water used, and that it will create a greater general interest in the efficient management of irrigation enterprises. Mr. Adams wishes to acknowledge the assistance of several members of the field force of this Office, as well as that of J. C. Wheelon, E. R. Morgan, R. L. Parshall, C. G. Jones, W. E. Bowen, F. G. Tracy, S. W. Cressey, and H. J. Quayle.

It is recommended that this report be published as a bulletin of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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DELIVERY OF WATER TO IRRIGATORS.

INTRODUCTION.

This bulletin is intended to give a description and review of the best features of the delivery of water to irrigators as disclosed by practice in the irrigated sections of the United States. It is not a complete treatment of the subject, because nearly every canal presents interesting points of difference from other canals, and the data on which it is based come from but forty or fifty systems. However, the systems from which information has been drawn are among the best managed in this country, and they at least show the best typical practice in this important branch of canal management.

More of the systems selected for description are located in California than in any other State. This is because it has been possible to gather data about more systems in California than in any of the other States, and not necessarily because more can be learned from California practice than from practice elsewhere. However, outside of the canals operated by the United States Reclamation Service, the canals around Riverside, Cal., have the most complete systems of delivery to be found in this country; yet the delivery systems there are relatively no more complete than those, for instance, on the Consolidated Home Supply and Larimer County canals, in Colorado, or on the Bear River Canal, in Utah. Under the Riverside and other southern California canals water for irrigation has reached its highest value in this country, and it is natural that more attention should be given there to efficient management than on canals where water has a lower duty and is less valuable.

In addition to the 11 California canals whose delivery systems are described, North Poudre, Larimer County, Consolidated Home Supply, and Rockyford canals, in Colorado; Wheatland Canal, in Wyoming; the Farmers' Canal, in Montana; Upper, South Jordan, Utah and Salt Lake, Davis and Weber Counties, and Bear River canals, in Utah; Nampa-Meridian Irrigation District Canal, in Idaho; Sunnyside Canal, in Washington; two small canals in Hood River Valley, in Oregon; Truckee-Carson irrigation project, in Nevada; Tempe Canal, in Arizona; and Northern and Pecos canals, in New Mexico, are included.

Field data were gathered during the irrigation season of 1908 from all of these canals and from those included from California. Besides, the irrigation reports of the Office of Experiment Stations were drawn upon for many suggestions, pertinent to the subject, that have been included in them from time to time, and notes taken in the field prior to beginning this bulletin were used whenever pertinent.

THE IMPORTANCE OF WATER DELIVERY.

After a canal is completed it is found that questions yet remain for decision that are far more perplexing than the mere construction of ditches. Aside from individual or small partnership ditches, probably no canal has been constructed in this country of which this has not been true. How to manage a canal so that each irrigator shall receive water in the amount and at the time required by his crops; how to divide water so that each irrigator shall receive the amount to which his water-right contract or his interest in the canal entitles him; how to organize a force and a system for water delivery that will accomplish both of these results without friction and at a cost irrigators will pay, are questions that no canal management has been able to settle except by long and costly experience. Yet these are questions the solution of which in a large measure determines the success or failure of a system.

While practically all canals have more or less satisfactory systems of water delivery, those on some canals are very much better than on others, and probably on few if any canals are those who are charged with water delivery fully satisfied with the methods in use. Every canal superintendent or manager realizes that his biggest problem is the measurement and delivery to the farmers of the water carried in his canal, and all of them eagerly seek information about the delivery systems used elsewhere. Every such official realizes that irrigators know only one test of successful canal operation—an ample water supply when and where needed. Especially regarding the details of water delivery—methods and devices for measurement, books for keeping field notes, forms for making reports and keeping records, plans of rotation or continuous delivery, and kindred questions—information is most eagerly sought. It is for this reason that this bulletin is wholly confined to the presentation of such information.

SYSTEMS USED ON TYPICAL ENTERPRISES IN CALIFORNIA.

THE GAGE CANAL COMPANY.

The plan of water delivery used on the Gage Canal at Riverside, Cal., is perhaps better known than any other in this country. The water carried by it has the exceptional agricultural value of $1,000 per miner's inch, and the need for accurately measuring the water and keeping records of its use has never been questioned.

The canal is controlled and managed by the Gage Canal Company. In addition to this company there are several entirely separate interests concerned in the delivery of water to irrigators, of which the largest and most important are the East Riverside Water Company and the San Jacinto Water Company. The former comprises the holders of 696 inches of water[a] granted by the Gage Canal Company to Mathew Gage. This company has issued its own stock in exchange for these rights and controls the distribution to the users of all the water drawn in section 2, comprising the second 5 miles of the main canal. The Gage Canal Company delivers all the water drawn from section 3, comprising Arlington Heights. The San Jacinto Water Company receives a small supply at the lower end and delivers it independently of either of the other companies. The East Riverside company pays its proportion of the expense of maintaining and operating the canal in sections 1 and 2 to the Gage Canal Company, which pays all the bills pertaining to the expense of the system and prorates them among the small interests. The irrigators in Arlington Heights own stock in the Gage Canal Company and pay their respective shares for maintaining and operating the canal.

The water supply for the Gage Canal is derived from flowing artesian wells in the bed of Santa Ana River and from wells pumped by a number of electric pumping plants. The main canal is 20.16 miles long. There are 22 pressure pipe lines, averaging 1.5 miles in length, supplying Arlington Heights. The main pipe lines are of riveted steel varying from 10 to 6 inches in diameter. The branches are of riveted steel also, 6, 5, and 4 inches in diameter. In addition to the pressure pipes of riveted steel, a few blocks close to the canal receive water from concrete pipes not under pressure. The East Riverside Water Company has 30 open laterals averaging 0.5 mile in length, and 2 pressure pipe lines of riveted steel varying from 12 to 4 inches in diameter, each about 5,000 feet long. The remainder of the system is covered by gravity lines of cement and vitrified clay pipes, ranging from 12 to 6 inches in diameter. The gravity lines have few laterals and usually each covers 1 holding.

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[a] The legal miner's inch in California is one-fortieth of a cubic foot per second. The customary miner's inch and the one which enters into most of the old contracts in southern California is one-fiftieth of a cubic foot per second. Where the miner's inch is used in this bulletin in describing the systems of southern California the latter is meant.

The water right under these systems is 1 miner's inch (4-inch pressure), or 9 gallons per minute for each 5 acres. The amount required for the planted lands to date is about 1,740 miner's inches, there being 8,684.40 acres irrigated under the entire canal, 3,484.40 of which are in the district controlled by the East Riverside Water Company.

The main irrigation season begins in April or May and continues to November, the heaviest application being made in the early spring. During dry years considerable water is run from November to May.

MAINTENANCE AND OPERATION.

An engineer is at the head of all deliveries and of all maintenance and operation. The force under him is enumerated in full below, the duties and salaries of each man being stated. While this force attends to both canal maintenance and operation it is concerned chiefly with water delivery.

For the water sources, headgates, section 1 and part of section 2, comprising the upper 5 miles of the main canal, the following are employed:

(*a*) A superintendent of water sources. Salary $125 per month; not an engineer.

(*b*) Four men to care for pumping plants, at $2.25 per day each. These men visit the 12 pumping plants at intervals of one and one-half hours both day and night.

(*c*) Carpenter and handy man for repairs, at $2.50 per day.

(*d*) One man, at $1.75 per day, to care for delivery to the Hunt & Cooley ditch, clean canal of weeds, and make periodical visits to the flumes in the upper section of the canal, a distance of 5 miles from headworks.

For the East Riverside section, the lower end of section 2, the following are employed:

(*a*) A head zanjero, at $115 per month, with no conveyance furnished. Reports to the office of the company at Riverside immediately after noon daily and receives orders for water, left there by telephone or in person. Attends to delivery of water from the lower 4 or 5 miles of main canal in section 2 and is responsible for maintenance of this portion of the canal.

(*b*) One assistant zanjero, at $90 per month, who patrols the upper 3 miles of canal and delivers 235 inches to irrigators, including 35 inches to the Artesia Water Company.

(*c*) One man to attend to canal cleaning, at $1.75 per day.

For Arlington Heights section (sec. 3) the following are employed:

(*a*) A head zanjero, at $150 per month, with no conveyance furnished. He oversees all delivery in section 3, receives reports from the assistant zanjeros, and makes all reports to the engineer at Riverside. He is responsible, also, for the condition of the canal and pipe lines in his section.

(*b*) Two assistant zanjeros, at $85 per month each, and no conveyances furnished. Each makes deliveries within his section of the canal. This, however, is necessary only during the summer months; during the remainder of the season the head zanjero takes part of the work and one of the assistants the balance.

(*c*) One man, at $3.25 per day, and an assistant, at $1.75 per day, to care for pipe lines and hydrants under the direction of the zanjeros. These men are employed about ten months in the year.

(*d*) Two Japanese, at $1.75 per day, who report to the head zanjero three times daily the amount of water entering Arlington Heights section and discharged to the San Jacinto Water Company, and the amount of water in the lower section of the canal.

(*e*) Four Japanese, at $1.75 per day each, employed during six months of each year to clean canals of grass and other vegetable growth.

(*f*) One night man, a Japanese, at $1.75 per day, whose duty it is to take out of the canal the moss that is collected by a grating about 1,500 feet above the lower end of the canal and to keep clean a screen at the lower end of the canal.

PLAN OF DELIVERY.

Arlington Heights section.—Water is delivered in the Arlington Heights section principally through pressure pipes of riveted steel, each main pipe line covering two tiers of 10-acre tracts, which are laid out in regular blocks, the lots being intersected at regular intervals by streets and avenues. Each irrigator is entitled to the equivalent of a continuous flow of one-fifth miner's inch per acre, but as it would be impracticable to handle such a flow, water is allowed to accumulate and is delivered in rotation. About 80 or 85 per cent of the irrigators permit it to accumulate for forty-five days, a few irrigate every sixty days, and the rest irrigate every thirty days. The owner of a 10-acre tract whose share of water has been accumulating for sixty days is entitled to a 30-inch flow for ninety-six hours. Except in the spring, when the land is relatively loose from plowing, this amount can not be held on the land so long, and consequently few irrigators use their full allowance of water. Water is delivered on all parts of the system at the same time, 25 or 30 users receiving water at the same time. When an irrigator desires water he makes written application to the company on forms furnished to him. The by-laws of the company (Art. IX, sec. 2) provide that "he shall give the corporation at least four days' notice of such desire and accept the water on any day or days that the company may be able to arrange for the supply thereof." The canal company will not recognize orders received in any other form and will receive orders only through the office. The orders received at the office are segregated by zanjeros' districts, the chief zanjero retaining those which he will personally fill and giving to the assistant zanjeros those for their respective districts. The company acknowledges receipt of orders on postal cards, stating when water will be delivered. The forms of application and receipt are as follows:

Form of order for water from the Gage Canal Company.

Date ...., 190...

No. of inches.........................

Block .... Lot. ....

From ....

To ....

Water Order. RIVERSIDE, CAL., ..., 191—.

THE GAGE CANAL COMPANY.

Please deliver ...... inches of water for use of lots ...., block ...., commencing on the morning of ......, the .... day of ......, 190.., for .... days.

(Signature.) ....

The company will not undertake to deliver water unless this form, properly filled up and signed, is left at the office of the company, 646 Seventh street, at least four (4) days before the water is required. Water will be delivered to shareholders in accordance with Section II of Article IX of the company's by-laws, each order having precedence according to the date of its delivery at the company's office as above.

N. B.—Anyone found tampering with the hydrants, measuring boxes, or any of the company's property will be prosecuted under sections 469, 592, 625 of the penal code.

Form used by the Gage Canal Company for notifying irrigators of time water will be delivered.

RIVERSIDE, CAL., ..., 191...

DEAR SIR: Your water order of ...... received to-day. Water will be delivered ......

THE GAGE CANAL COMPANY.

Zanjero's office hours: 6 to 6.30 a. m.; 1.15 to 1.45 and 6.30 to 7 p. m. Kindly phone if necessary during above hours.

Sections of the canal about 1,500 feet above the lower end have been enlarged and cement lined to form equalizing basins to overcome the fluctuations so often found at the lower ends of canals. They are large enough to hold a flow of 60 inches for three days, and have been found to insure better service to the lower irrigators and permit of a more uniform flow to the San Jacinto Water Company.

The East Riverside Water Company.—At the beginning of each season the secretary of the East Riverside Water Company gives a statement to the head zanjero showing the amount of water to which each user is entitled during the ensuing season. The zanjero then arranges with the users as to what day or days of each month they desire to receive water, and the same days are held throughout the season, each irrigator receiving water every thirty days. The regularity of the schedule is not allowed to be broken by the last day in a 31-day month, but during that day the water either is run into the reservoirs or a little extra supply is given to those who for any reason have not received a full share. Each day at noon the assistant zanjero reports to the head zanjero the amount of water needed to supply the users in his district the next day. The head zanjero states this amount, together with what his own district will require, to the head zanjero of the Gage Canal Company. Each irrigator gives written notice to the zanjero of the amount of water desired and for what part of his allotted period it is desired. The notices are not required to be sent through the office of the company, as in the Arlington Heights section, but are taken by the head zanjero on his daily visit and distributed between the assistant zanjeros and himself for filling. No rules or regulations have been issued by the company for the guidance of the irrigators or the zanjeros, but the zanjeros have been allowed to work out a satisfactory system, and they are supported by the directors of the company. As in the Arlington Heights section, deliveries are made only for periods of twenty-four hours or multiples thereof. The zanjeros do not make changes in the delivery at night under either of these systems.

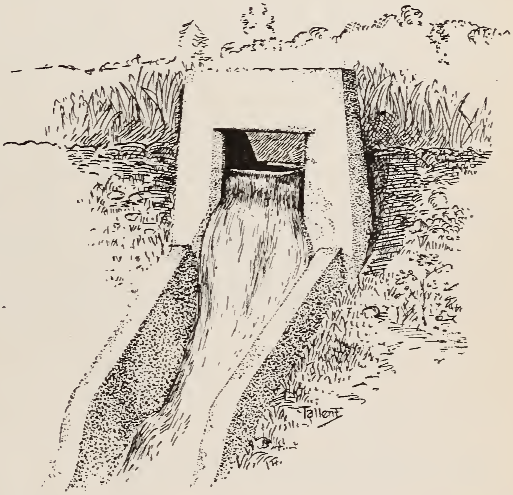

Fig. 1.—Concrete hydrant and measuring weir used by Gage Canal Company.

Measuring devices.—The first point of measurement on the main canal of the Gage company is at the township line, 5 miles below the headgate, where there is a rectangular weir with a crest length of 160 inches and an automatic water register. In addition to the continuous record of the water register, three readings of the amount of water passing over the weir are taken daily and reported to the superintendent of water sources. The next point of measurement is at weir No. 2, where water is delivered to Arlington Heights (sec. 3) over a 100-inch rectangular weir with a register. The third point is at the lower end of the canal, where water is delivered to the San Jacinto Water Company over a 20-inch rectangular weir provided with a water register. At the head of each main lateral, both in the East Riverside and Arlington Heights sections, there is a 20-inch rectangular weir, on which measurements are made twice daily. At each point of delivery on Arlington Heights there is a 10-inch rectangular weir set in the side of a cement hydrant box (fig. 1). In the section covered by the East Riverside Water Company there is a 10-inch or a 15-inch rectangular weir wherever a branch lateral leaves the main lateral, and a hydrant box at each point of delivery to irrigators. These boxes are open on top and have the weirs set in the center of a cement partition. On Arlington Heights the flow into the main pipes and also into the hydrants is controlled by regular low-down waterworks valves.

RECORDS, FORMS, AND CHARGES.

A complete record of water delivery is kept by the Gage Canal Company, but none is kept by the East Riverside Water Company, except notes of daily deliveries made by the zanjeros in scratch books furnished by themselves and never turned in to the office. On Arlington Heights each zanjero enters all deliveries in a scratch book, which is not turned in to the company, and from this makes up a daily report in duplicate on the form printed below, sending the originals to the office at Riverside and retaining the duplicates.

Form of zanjeros' daily reports used by the Gage Canal Company.

GAGE CANAL COMPANY.

Zanjero's Daily Report.

Date, ———, 190—.

Trust Co.			Orange Co.			Other growers.				Remarks.
Lot.	Block.	Inches.	Lot.	Block.	Inches.	Name.	Lot.	Block.	Inches.	

Water used above weir No. 2, ——— inches.
Water passing weir No. 2, ——— inches.

Total, ——— inches.

——— ———, *Zanjero.*

A number of years ago a ledger was started by the Gage Canal Company and kept for a year or two, in which a complete record of the deliveries to each irrigator was entered from the zanjeros' daily reports. The company has come to realize that this record is very valuable, and during the season of 1908 it entered the records for the years during which the ledger was not used. The intention is to maintain the ledger complete hereafter, as it will require not more than fifteen minutes each day to make the entries. The ledger sheets are 17 by 24 inches, and each sheet has a space for the records of delivery to 48 irrigators for twelve months. On these sheets the names of the irrigators are entered, with the exact location by lot and block and the area of the holdings, the shares of stock owned by each, the day water was turned on each month, the number of days it ran, the date it was turned off, and the total amount delivered.

The cost of water delivery and distribution by the Gage Canal Company on Arlington Heights during the past few years has ranged from 50 to 65 cents per acre. In 1901 it was 64 cents; in 1903, 51 cents; in 1904, 54 cents; in 1905, about 52 cents; in 1906, about 47 cents; and in 1907, about 53 cents. This included about two-thirds of the salary of the secretary and the salaries of the zanjeros, but no part of the salary of the engineer. In the section operated by the East Riverside Water Company the total expenses charged to water delivery in 1908 were $3,310, or an average of about 95 cents per acre for the entire 3,484.40 acres supplied.

THE RIVERSIDE WATER COMPANY.

Another important system at Riverside is that of the Riverside Water Company, which irrigates 6,500 acres of citrus orchards, 1,500 acres of alfalfa, 200 to 300 acres of grain in dry years, and 500 acres of miscellaneous crops. It receives water from Warm Creek, artesian wells, and pumps, and has a maximum flow in its two main branches of 3,000 miner's inches, or 60 cubic feet per second. This is maintained with very little change throughout the irrigation season. The larger branch, known as the Upper Canal, is 19 miles long and the smaller branch, known as Lower Canal, 12 miles long. Leading from these two branches are approximately 40 miles of laterals, consisting of both open ditches and pipe lines. About 750 irrigators are supplied with water.

PLAN OF DELIVERY.

Water delivery on this system is in charge of a superintendent, who attends also to the maintenance of the canal and pipe lines and receives a salary of $125 per month. Under him, in direct charge of delivery, is a head zanjero at $120 per month and three assistant zanjeros at $108 per month. One of the zanjeros is employed but eight months in the year, and each furnishes and feeds two horses. For the purpose of delivery the system is divided into four districts. One zanjero covers Upper and Lower canals for a distance of about 10 miles on each canal; the next, about 3.5 miles on each canal; the third, about 3 miles on each canal to the end of one; and the fourth, the remaining canal to its lower end, a distance of 9 miles. Each zanjero, except the one on the upper section, receives orders and makes reports by telephone at noon of each day. The one on the upper section receives his orders and makes his reports daily at the office in Riverside in person.

The basis of water delivery followed by this company differs entirely from that of either of the companies described previously. No water is delivered unless applied for in writing and paid for in advance of delivery. The users, instead of being restricted to specific amounts of water at regular intervals, may receive it whenever and to whatever extent desired except in times of unusual shortage, when the supply is prorated according to the number of shares held. The rules of the company require that a notice of contemplated prorating must be published at least thirty days before it is begun. To govern the matter of orders for water and payments therefor, the following rules have been adopted and are strictly enforced:

(1) Orders must be placed in the office of the company three full days before the date of delivery.

(2) Continued orders must be placed in the office, or with the zanjero in charge, at least twenty-four hours before the expiration of the preceding order.

(3) Water will be charged at the rate prevailing at the time of delivery.

(4) Those having water paid for in advance must give the same notice as others, either at the office of the company or to the zanjero in charge.

(5) If water is sold at a less price than the rate fixed by the city trustees, the price may be advanced at any time without notice, and all water run thereafter shall be charged at full rates.

(6) Zanjeros are instructed to receive no money for water nor to receive water orders, except continued orders. The company will not be responsible for money or orders unless taken at the office of the company.

Every day during the irrigation season the total flow received into the system is divided among the zanjeros, according to the orders received, each taking the proportion to which he is entitled as nearly as he can without measurement. Long practice has enabled the zanjeros to do this with approximate accuracy. Each zanjero delivers to about 15 irrigators daily, varying from 10 to 50 inches to each. Usually 10 inches is furnished for each one for twenty-four hours every four or five weeks.

The Riverside Canal has the following devices for water measurement: A rectangular weir and Watson water register at the head of the main canal, to measure the supply from both surface and artesian sources; a 48-inch rectangular weir at each pumping plant, over each of which there is an average flow of 200 miner's inches; and a box for measuring miner's inches, at the head of each main lateral and at each point of delivery to users, where there is sufficient fall for its use (fig. 2). Where the fall is not sufficient the laterals have been rated with a current meter, and in some cases a scale has been attached to the box showing the flow in inches at different depths.

RECORDS AND CHARGES.

The records of water flow and delivery kept by this company consist only of the register sheets taken from the water registers at the head of the canal and the zanjero's reports of daily delivery, submitted by telephone. No records are kept of the flow in the main laterals. This flow varies from day to day and during the day as required to fill orders. No report forms are used for measurements taken by the zanjeros, and no weekly reports are filed in the office.

From 1885 to 1888 water was sold at a flat charge of 7.5 cents per 24-hour inch; in 1888 the charge was raised to 10 cents, in 1898 to 15 cents, and in 1900 to 25 cents. In 1903 the company instituted a schedule of rates, varying according to season, on the theory that water is more valuable when scarce than when plentiful. The schedule of charges per 24-hour inch since that time has been as follows: July 15 to October 31, 25 cents; November 1 to February 28, 10 cents; March 1 to May 31, 15 cents; June 1 to July 15, 20 cents. With a uniform flow throughout the season the average charge per 24-hour inch would be 16⅞ cents. Under three of the laterals the water is not charged for on this basis, but a flat rate is made of $12 per acre per year. This plan is followed also in about 12 cases where water is raised from the canal to lands above by means of current wheels or motors, and also in some cases where facilities for measuring water are lacking.

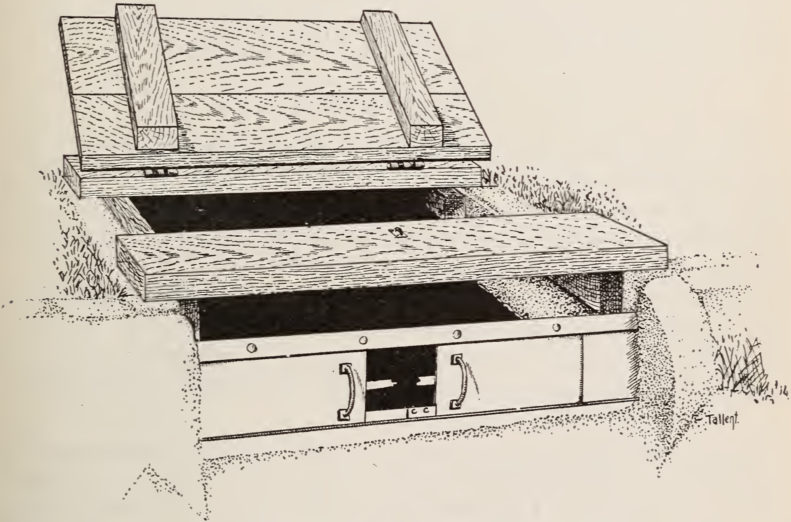

FIG. 2.—Device used by the Riverside Water Company for measuring miner's inches.

The irrigators under the system are satisfied generally with the plan of delivery because they can get water as often and in such quantities as they desire, provided it is paid for in advance, and as no schedule of delivery has been adopted they are not compelled either to irrigate at a certain time, regardless of whether or not they wish water, or lose their turn. Some of the users, however, object to the cost of water, which is said to average about $10 per acre per annum, but these objections are not made to the system of delivery.

The total cost of delivery on the system in 1908 was $6,351, or about 73 cents per acre. The cost consisted of $4,896 for zanjeros, $1,080 for the secretary, and $375 as one-fourth of the salary of the superintendent.

THE SANTA ANA VALLEY IRRIGATION COMPANY.

This is a cooperative company irrigating 17,000 acres of citrus and walnut orchards near Santa Ana from the Santa Ana River and wells. The main canal is 12 miles long, and has a maximum flow of 4,500 inches and an average flow of 1,400 inches. At the end of 12 miles it branches into two main laterals which, with the principal distributaries, aggregate 88 miles in length.

PLAN OF DELIVERY.

Water delivery under this system is under the direct charge of a superintendent, who receives a salary of $125 per month. Under him are five zanjeros, three of whom receive $70 each, one $65, and one $60 per month. A portion of the secretary's time is devoted to keeping the records of delivery.

During winter and spring, when water is plentiful, irrigators are allowed water when and in the quantity desired, as under the Riverside Water Company's system. In the main irrigating season the water is rotated according to rules and regulations of the company, rule No. 2 being as follows:

> Water will be served from the company's gates only; it will be limited at all times to one hour to the share, unless it be running to waste or be otherwise ordered by the board of directors, and will be run in turn of gates, except when running to waste, the right-hand gate being served first, where two come opposite, and the larger streams before the smaller ones.
>
> When the water is running to waste and is therefore on application, the limit is hereby suspended, except in the case where another irrigator needs the same ditch or gate, in which case the limit shall be retained, including only the stock appurtenant to the land irrigated through said ditch or gate, and be enforced from the date of the first of the conflicting applications, on twenty-four hours' notice, until such other irrigator has been served to the amount of his limit.
>
> When water is thus on application, the zanjeros shall serve the irrigators in the order of the application on the company's books, shall cancel every application where the irrigator refuses, after due notice, to take the water when his turn comes, and shall serve no irrigator a second time on the same call while unfilled applications from other irrigators remain on the company's books.

Rule No. 3 provides that water shall be delivered only in definite heads to be measured under 4-inch pressure above the top of the opening through which it is measured, at rates estimated and fixed from time to time by the board of directors. A full head is 100 inches, measured through an opening 33⅓ inches wide by 3 inches deep. Frequently less than a full head is delivered.

The water is rotated between the two main branches. Four weeks are required to cover the entire irrigated area, the time being divided about equally between the two branches. The date of beginning each run is posted in public places and published in the local newspapers. When water is "on application," that is, ample for all demands, any irrigator may obtain a supply during any or all runs by making application at the office of the company forty-eight hours in advance of delivery and paying for it at that time. When the supply becomes too low to deliver on application, strict rotation is followed, beginning at the upper ends of the laterals. The time the full head, 100 inches per acre, is delivered during periods of rotation varies with the supply available at the source, the minimum being twenty minutes. If a fractional head is used, the time is correspondingly increased. The stream commonly used for citrus orchards is 25 inches. The quantity of water usually available per acre is not enough for citrus orchards but more than enough for walnuts, the latter requiring only two irrigations, one early in the spring and the other early in the fall. This has given rise to the common practice of renting shares of stock. The regulations of the company permit this, with the proviso, however, that such renting shall be in writing and good for only one year, but subject to renewal at the end of the year. The form for making such temporary transfers is very simple, being merely an order on the company to "allow ——— ——— to use —— shares of my water stock."

The zanjeros are supposed to be on their respective beats at 6 a. m., and to report to the office at Orange between 11 and 12 o'clock for orders. They are required to visit every gate taking water at least once each day but are not out at night except in emergencies.

The measuring box is merely a cemented section of the lateral with a measuring board set in. The water is forced into the boxes by stop gates set in the cemented sides (fig. 3). The farm laterals at the points of measurement are uniformly 33⅓ inches wide, and if a full head is desired an opening the full width of the lateral and 3 inches high is used, sufficient water being turned into the box to cause it to stand 4 inches above the top of the opening. If only 50 inches is desired, an opening half the width of the box is used. This opening is at one side of the lateral, however, and gives an uneven contraction. The inch, as measured by these boxes, is not accurate, the contractions are not complete, and it is not the legal miner's inch of the State.

RECORDS, FORMS, AND CHARGES.

As all water delivered by this company is paid for at regular rates, complete records of delivery are necessary. Each zanjero is provided with a field book, ruled in blank, for keeping daily records. In this book are noted (1) the name of each irrigator served; (2) the exact time delivery is begun and ended; (3) the size of head delivered to each, and the ditch and gate from which delivered; (4) the number of hours of day water and the number of hours of night water taken by each; and (5) the charge for the water delivered. This field book is in the form of an ordinary time book, with a line to each name and a column to each day. From these books the zanjeros make up the daily report cards sent to the office. A copy of this daily report card is given here.

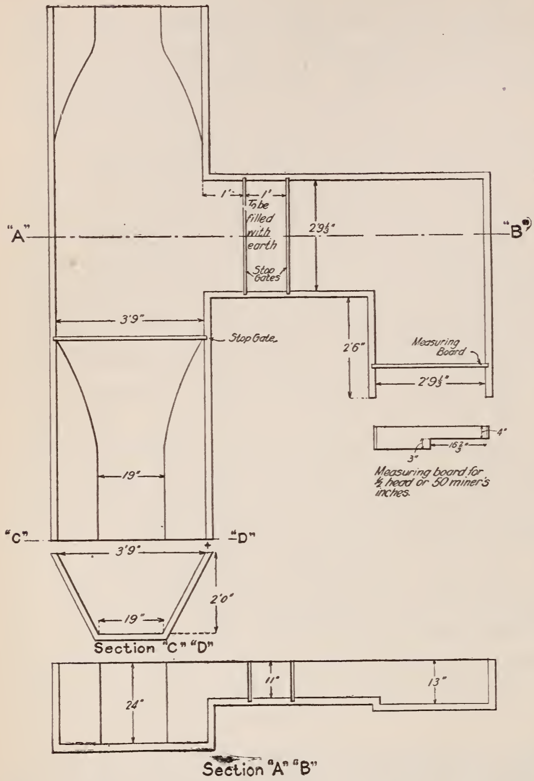

FIG. 3.—Device used by the Santa Ana Valley Irrigation Company for measuring miner's inches.

Form of daily report card used by the Santa Ana Valley Irrigation Company.

DAILY REPORT CARD. SANTA ANA VALLEY IRRIGATION COMPANY.

I certify that I have delivered water to-day as reported below :

No. ----
------ 190--
------ ------, Zanjero.

Name.	Head.	Ditch.	Gate.	Started a. m.	Started p. m.	Stopped a. m.	Stopped p. m.	Shortage.	Hours.		L. F.	Amount.
									Day.	Night.		
....	......	......	......	....	....	....	....	....	......	......	......	....
....	......	......	......	....	....	....	....	....	......	......	......	....
....	......	......	......	....	....	....	....	....	......	......	......	....
....	......	......	......	....	....	....	....	....	......	......	......	....

When an irrigator applies for water at the office of the company he brings a small book, similar to a bank passbook, in which the secretary enters the amount of payment and the time water is wanted. An entry of the payment is also made in a loose-leaf ledger, and the charge is later entered from the daily report of delivery sent in by the zanjero. The passbook and the ledger thus give a complete statement of each transaction. The forms of both the passbook and the ledger are suggestive, and are given below:

Form of passbook used for payments for water delivered by the Santa Ana Valley Irrigation Company.

Date.	To—	Date.	Head.	Day.	Night.	Amount.	Date.	Cash.	Amount.

Form of water ledger used by the Santa Ana Irrigation Company.

Date.	To—	Date.	Head.	Day.	Night.	App. book.	Debit.	Credit.	Balance.

The usual charge for water delivered during the spring and summer is 30 to 40 cents per hour for a full head of 100 inches. In winter the charge is only 20 cents. Different rates have been established for water delivered during the day and that delivered at night, the night rate being 15 cents when the day rate is 30 cents per hour. The by-laws provide that from March 1 to September 30 day hours shall extend from 5 a. m. to 7 p. m. and from October 1 to February 28 from 6 a. m. to 6 p. m. When the supply falls the head usually remains the same, but the length of time is reduced, sometimes to twenty minutes.

The charges for quantities over one-tenth of a full head are on the regular basis rate; for one-twentieth of a full head the rate is increased 50 per cent, and for one-hundredth of a head it is increased to four times the basis rate, etc. Other rates for domestic and stock purposes and for sprinkling and spraying, where water is taken in any other manner than from the regularly measured streams, are as follows: Twenty-five cents per month for each family; 25 cents for filling each cistern or storage tank; 10 cents for each sprinkling or spraying tank; 5 cents per month per head for horses, mules, and cattle; and 2.5 cents per month per head for sheep and hogs: The minimum charge for turning water is 25 cents. Delivery under these rates must be reported by the zanjeros at the beginning of each month for the ensuing month.

THE REDLANDS WATER COMPANY.

This company supplies water to about 1,400 acres of citrus orchards in the immediate vicinity of Redlands, the supply being received from several sources. The main distributary is a pipe line about 8 miles long with 4 or 5 miles of main distributing laterals. During the principal irrigating season—May 1 to October 31—the flow in the main pipe line averages about 300 inches and is quite regular; in winter it fluctuates according to the local demand. About 180 irrigators are served under the system.

The entire work of delivery is attended to by one zanjero, working under a superintendent having general oversight of both delivery and maintenance. The zanjero goes once and sometimes twice daily to all points on the system where water is being delivered. The company has issued 1,500 shares of stock and water is prorated among the owners of these shares, the usual irrigating stream being 25 inches. A definite schedule, giving each irrigator water once every thirty days and showing the time he is to receive it for every run during the season, is arranged at the beginning of each season. There are no departures from this schedule; if a user fails to take water in his regular turn he has no further chance until the next run. The basis of delivery is the 24-hour inch, and no stream is delivered for a period less than twenty-four hours. The number of 24-hour inches delivered per share varies as the season seems to require; in a recent season five 24-hour inches were delivered per share during the first run in May and six 24-hour inches at each of the five subsequent runs, making a total of thirty-five 24-hour inches per share for the season.

The distributing system and measuring devices of this company have been worked out with a good deal of detail and care. All of the pipe lines are of vitrified clay and range from 16 to 5 inches in diameter. At the lower end of the Bear Valley canal one 42-inch and one 48-inch Cipolletti weir are installed to measure the flow into the Redlands reservoir, which is cement lined and has a capacity of 3,000,000 gallons. This reservoir is one of the important features in the distributing system, as it equalizes fluctuations in the supply and provides a steady flow into the pipe lines leading to the farms. Water leaves this reservoir through two 8-inch pipes, which empty into a large box out of which a 12-inch pipe leads to a smaller box where a 49-inch rectangular weir is installed. This weir is not in use at present, and the water is measured over a 100-inch rectangular weir at box No. 1, a short distance below. The boxes are connected by two 16-inch pipes. There are two pipes, a 16-inch and a 12-inch, leading from box No. 1 to three 30-inch rectangular weirs at distributing box No. 2. The pipes from these weirs are so arranged that some water is diverted to the Center street box and some to the high-school line at box No. 4. At box No. 5, on the Center street line, there are three 30-inch rectangular weirs from which the water is measured into the laterals. At the head of each main lateral and at the highest point on each 10-acre tract the water passes over a 15-inch rectangular weir. There are two 20-inch and one 30-inch rectangular weirs in box No. 2 on the high-school line over which the water passes to the main laterals and farms. In addition to the delivery system as described above, water is received from the Bear Valley Canal at five points above the Redlands reservoir and also from the Bear Valley Irrigation Company's measuring box at Cajon street, known as Big Box. At the weirs over which water passes into the Redlands reservoir a Watson register is installed, and the record sheets are preserved in the office of the company. This register has not been in use for the past three years, owing to the ample supply of water, but it is intended to use it hereafter. No records have been kept of the water received from the various sources, but the company believes that such records would be very valuable. The Bear Valley Irrigation Company keeps a record of the amount it turns to the Redlands Water Company.[a] In addition to this record the zanjero keeps a record of all deliveries to users in an ordinary time book, simply to show that water has been delivered in accordance with the seasonal delivery schedule.

The total cost of water delivery under the system is given as $1,810 per year, or about $1.30 per acre. The zanjero receives a salary of $80 per month, and the superintendent, who has general oversight of both maintenance and delivery, receives $50 per month. The remainder goes for office expenses and for having water turned to the company from the Bear Valley Canal.

THE CRAFTON WATER COMPANY.

This company supplies 1,700 acres of citrus orchards in the vicinity of Redlands. The distributing system is composed of 1 mile of open ditch, 2 miles of main vitrified pipe line, and 2 miles of distributing pipe lines. It has a maximum flow of 1,700 miner's inches and an average flow all summer of 500 miner's inches. There are 80 irrigators under the system, and 18 to 20 are supplied with water each day. The owner of each acre irrigated holds 1⅗ shares of stock in the company and the total supply carried is divided among the users proportionally to the number of shares held.

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[a] Since this report was written the Bear Valley Irrigation Company has been made a part of a mutual company, and is owned and operated by the irrigators.

The force employed in water delivery consists of a zanjero, who distributes the water and maintains the pipe lines, with such additional help as he needs at the time of cleaning and making repairs. The zanjero's time is devoted to making deliveries from 7 o'clock in the morning until noon of each day, and in doing this work he covers about 25 miles. He returns home at noon and at 3 p. m. he again goes over the system to check up his deliveries. He makes no changes on the afternoon trip, all streams running for periods of twenty-four hours or multiples of twenty-four hours. He is directly under the general manager, who maintains only a general oversight of the system and receives but $20 per month.

The size of stream delivered to irrigators varies with the supply. At the beginning of the season the supply available for the next thirty-five days is estimated as nearly as possible, being usually about seven 24-hour inches per acre. A new schedule is arranged for each subsequent irrigation to conform to the available supply. The schedule of rotation is not arranged in accordance with the location of the holdings, but in the order in which the applications were made at the beginning of the season. Most of the users take 15 to 40 inches as an irrigating head. The exact size is decided by the user, but the length of time the stream is run depends upon its size and the number of shares held by the user. The average stream delivered early in the season is about 25 inches, but by the end of the season it falls usually to about 15 inches. The water from the various sources before being distributed passes into a reservoir large enough to hold a flow of 2,000 miner's inches, or 40 cubic feet, per second for twenty-four hours. By keeping a depth of 10 feet of water in the reservoir the zanjero is able to eliminate all fluctuations in the supply and to keep an ample head at the hydrants, of which there is one at the highest point on each 10-acre tract. The distributing pipes leading to these hydrants are of cement and 6 to 12 inches in diameter, and are owned by the company.

A complete system of water measurements has been provided on this system. There is a 54-inch rectangular weir with a water register at the head of the ditch from Mill Creek, and a second weir and register at what is known as Green Spot pipe line, where water is received from the Bear Valley Water Company. At the outlet of the reservoir there is a 100-inch rectangular weir, but no register. Rectangular weirs, mostly with 30-inch crests, are placed at the heads of the laterals leading from the main ditch, a 15-inch rectangular weir at the hydrants on the 10-acre tract, and a 48-inch rectangular weir and register at the end of the main pipe where water is run to the Redlands Heights pipe line. With these registers the company is able to keep an exact account of all water entering and leaving the system other than that delivered to irrigators. The record sheets are kept by the president of the company as permanent records. The zanjero makes daily check readings from May 1 to October 31 at Mill Creek and Green Spot and at the outlet from the reservoir. He also makes notes in a small book of all deliveries to irrigators, but this record is not turned in to the office of the company.

The total annual cost of water delivery under this system is given as $1,500, or about 90 cents per acre. The salary of the zanjero is $1,020 per year and of the general manager $240 per year, the remainder being for incidental office expenses.

THE LUGONIA WATER COMPANY.

The Lugonia Water Company receives water from the Santa Ana River and the Bear Valley system and irrigates 3,360 acres of citrus orchards at Redlands. Water is delivered through 11 miles of main pipe and 4 or 5 miles of laterals composed of vitrified pipe from 14 to 16 inches in diameter. There is a regular flow of 466 inches available from May 1 to October 31; during the winter months the average drops to 300 inches. One hundred and forty-eight irrigators are served.

Water delivery is attended to entirely by one zanjero. The 466 inches available during the main irrigating season is divided into two equal streams and but two irrigators are served at a time, each receiving the stream of 233 inches per share for twelve minutes, or two hours for 10 shares, the usual number of shares held. A schedule of delivery is prepared at the beginning of each irrigating season and the intervals fixed at thirty days. The custom is, however, to receive a half supply every fifteen days rather than a full supply every thirty days. Some irrigators still prefer to water their entire acreage at one time and this is arranged for through neighboring farmers pooling their interest, one receiving the entire 233 inches at one run and the other receiving it at the run fifteen days later.

All of the water received and delivered is measured over rectangular weirs. Besides the one at Sunnyside divide, where the supply is received from the Bear Valley system, there is a 40-inch weir at the head of each main lateral and at the point of delivery on each 10-acre tract. The simple plan of delivery makes records unnecessary. The supply not only is maintained at a stated amount throughout the year—466 inches from May 1 to October 31 and 300 inches from November 1 to April 30—but the season's schedule is adhered to strictly except when neighboring irrigators pool to take water every thirty days instead of every fifteen days. While this simple plan is in the main very satisfactory, some of the irrigators feel the need of a reservoir to store the water not really needed, as at present it must be used at a stated time or not at all, but if storage were possible smaller heads for a longer time could be permitted in certain cases.

The total annual cost of delivery is approximately $1,500, of which $1,200 is the salary of the zanjero and $225 the salary of the secretary. The cost per acre is about 45 cents.

THE SAN ANTONIO WATER COMPANY.

The San Antonio Water Company receives water from San Antonio Creek, two tunnels, and wells, and supplies 6,000 acres of citrus orchards in the vicinity of Ontario. Water is delivered through cement pipes, there being a main pipe about 15 miles long and 100 miles of 8-inch and 10-inch lateral pipes. The ownership of the system is divided into 6,000 shares and each shareholder receives his prorata share of the total supply available on the basis of the number of shares held. There are 600 irrigators under the system, the largest number of shares held by any one being 72, the smallest one-fifth share, and the usual number 5 to 10.

The general manager of the company is responsible for the delivery of water to irrigators, but the work is performed by a chief zanjero at $100 per month and one assistant zanjero at $75 per month. The company has a superintendent, but he has charge only of construction and maintenance. Both the chief zanjero and his assistant are furnished with motor cycles by the company. The chief zanjero prepares a rotation schedule for the entire season. Rotation is begun at the head of the laterals and is repeated at intervals of one month. The heads vary from 35 to 60 miner's inches, the average being about 45, and are run to the holder of each ten shares for twenty-four hours at each run. An average of one share is held for each acre irrigated, although some irrigators use as much as 1½ shares per acre. The two zanjeros together handle 20 heads at one time, the heads being kept uniform throughout each rotation. Although the water users know after the first run the hour and day they will receive water each month the chief zanjero gives them notice two days in advance in order that no water may be wasted by the user having forgotten to take it. If an irrigator does not want water when his turn arrives, he is passed until the next regular run.

Water is measured over galvanized-iron rectangular weirs 28 inches long set in cement inside of measuring boxes. These boxes are 4 feet square outside and made of cement or brick covered with cement, with walls 4 inches thick and a partition of the same material 12 inches from one side. They are 6 feet deep, stand 18 inches above the ground, and have galvanized-iron weirs set in the partitions.

The water from the main pipe line enters the smaller chamber made by the partition, is forced up and over the weir, falls into the larger chamber, and passes out through a 4-inch by 8-inch opening in a sheet of galvanized iron into the cement pipe line leading to the orchard. This opening is provided with a sliding plate used to regulate the length of the opening. Below the 28-inch weir there is an iron gate through which water is run when no deliveries are being made. The boxes are covered with boards and a hinged door provided with a lock. They are not always kept locked, however, and the gates are usually set by the irrigators with the permission of the zanjeros. Aside from the record of the total supply of water available, no records of delivery are kept, unless through some accident the schedule must be altered, in which case a note is taken of it by the zanjero and the record thus kept complete.

The total annual cost of water delivery under this system is given as $2,220, or 37 cents per acre. Of this amount, $2,100 is for salaries of the zanjeros and the remaining $120 for office expenses.

THE COVINA IRRIGATING COMPANY.

This company controls a small system at Covina, watering 4,500 acres of citrus orchards. The water supply is derived from the San Gabriel River and from a number of wells feeding four pumping plants. The distributing system is composed of 6 miles of mains, partly cemented ditch and partly cement pipe, and 30 miles of cement-pipe laterals. The maximum stream carried is 40 cubic feet per second, and the average about 12 cubic feet per second. The water of the system is prorated among the irrigators in accordance with the number of shares held by each, three being the usual number held per acre irrigated. The usual stream delivered is 25 miner's inches, although in some cases as much as 100 miner's inches is delivered.

Water delivery under the system is nominally in charge of the superintendent. The work, however, is left entirely to two zanjeros, the chief zanjero receiving $85 per month for eight months and $75 per month for four months, and his assistant receiving $75 and $70 per month, respectively, for the same periods. Delivery is begun at the lower end of the laterals and the apportionment is made on a basis of 25 inches for twenty-four hours for each 10 shares held. The stream delivered is uniform throughout the season, but the number of hours varies according to the supply, being lengthened usually to forty-eight hours in the fall. The zanjeros are required to give users forty-eight hours' notice of the exact time water will be turned to them. This notice was given formerly on printed forms, but now verbal notice in person or by telephone has been substituted.

The size of stream for each 10 shares held is kept constant throughout any one season by means of an equalizing reservoir holding a flow of 100 miner's inches, running for eleven days. If the river supply fluctuates, the zanjeros use this basin either as a supplemental supply to make up any deficiency or as a place to save any excess.

The weirs formerly used for measuring the water have been replaced by cement miner's inch boxes, 26 inches wide, 30 inches long, and 6 feet deep (fig. 4). The water enters through a cement pipe at the bottom of one end of the box and passes out through two openings on one side near the top. At the end opposite the point of entrance there is a waste way with two openings, each having a galvanized-iron crest 4 inches above the center of the openings in the side, which take care of minor fluctuations in the head. Directly below the waste way at the bottom of the box is the main waste way, regulated by an iron gate, which keeps a constant head of 4 inches above the center of the openings in the side. These openings are each 4 inches high and 12.5 inches wide, have galvanized-iron crests, and are closed when not in use with galvanized-iron gates. Many of the measuring boxes are provided with a series of discharge openings of different lengths, so as to deliver heads of different sizes, such as 10, 25, 50, and 100 inches, or a combination of two or three of these.

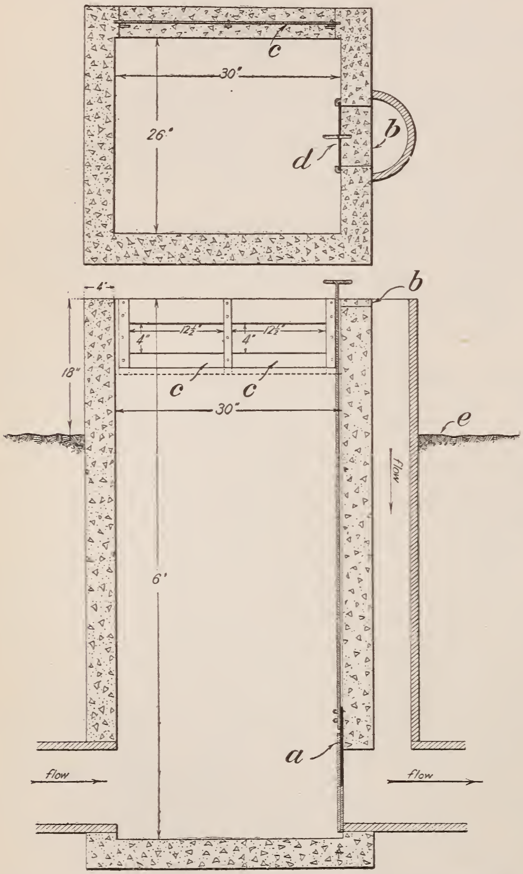

FIG. 4.—**Device used by Covina Irrigating Company for measuring miner's inches:** *a*, main waste way; *b*, overflow waste way; *c*, miner's inch openings; *d*, galvanized-iron crest of overflow waste way; *e*, level of the ground.

The two zanjeros make daily reports on the form shown below to the secretary of the company, showing the amount of water delivered to each user during the day, these reports being the basis of the water charges. Water costs the irrigator at the rate of $2.50 for 100 miner's inches for each twelve hours.

Form of zanjero's daily report, used by the Covina Irrigating Company.

ZANJERO'S DAILY REPORT TO SECRETARY COVINA IRRIGATING COMPANY.

Date……, 190..	Number of lateral.	Number of hours stock and alien.	Number of hours contract.	No. inches.		Amount.	
				Day.	Night.	Dollars.	Cents.
....	....	....	....	......	....	....	....
....	....	....	....	......	....	....	....
....	....	....	....	......	....	....	....

The total cost of water delivery under the system is given as $2,750 per year, or 60 cents per acre. Of this, $1,860 are paid in salaries to the two zanjeros, $800 being used as the salary of the secretary and for other office expenses. The superintendent, whose duties are almost wholly with maintenance, received $75 per month, but only $90 of his yearly salary is charged against water delivery in the above estimate.

THE AZUSA IRRIGATING COMPANY.

The Azusa Irrigating Company controls a small system at Azusa, which waters 4,043 acres of citrus orchards. The main distributary is a cement-lined ditch 3 miles long, with 3 miles of 36-inch to 14-inch cement-pipe mains and 35 miles of 8-inch and 10-inch cement-pipe laterals. The water supply of the system comes from San Gabriel River. The maximum flow carried in the main canal is 28 cubic feet per second and the average 12 cubic feet per second.

The president of the company has general oversight of water delivery, but devotes practically no time to the work. The detail of delivery is in charge of a zanjero, who is paid $100 per month for eight months and $60 per month for the remaining four months. Under the zanjero is a superintendent, whose duties are in connection with the maintenance of the system, although he sometimes assists the zanjero in water delivery. The secretary of the company devotes nearly all of his time to the bookkeeping and receives a salary of $50 per month.

Water is delivered to the 250 irrigators of the system in rotation, beginning at the heads of the laterals. The minimum stream delivered is 25 miner's inches, the maximum, 100 miner's inches, and the usual stream, 35 miner's inches. The usual size of holdings is 10 acres, and for such a holding it is customary to deliver 35 inches for twenty-four hours every thirty days, except in the case of small fruits, when delivery is made every ten or fifteen days. Users are permitted to receive any size of head within the minimum and maximum limits mentioned, but the time they may receive such head varies so that the total supply delivered may be kept within the amount due. The zanjero is required to give the users a verbal notice forty-eight hours in advance of delivery. As the supply in the system and the size of heads delivered to users vary, each schedule is arranged independently of the others to conform to the supply available from the river.

A miner's inch under 4-inch pressure is the unit of delivery. The measuring box is practically the same as that of the Covina Irrigating Company, the main difference being that the gate or orifice is of cast iron instead of galvanized iron. All of the measuring boxes are provided with locks, and no stockholder is allowed to raise any gate or divert any water without the consent of the zanjero, under penalty of a fine not to exceed $25 for each offense and having his supply of water shut off until such fine is paid. Only the owners of land inside of the Azusa water district are allowed to hold stock in the company, and no one is permitted to subscribe for less than three shares per acre.

The zanjeros forward daily reports to the secretary showing the water delivered, and from these reports the latter makes up the water charges. The report blanks are large enough to take a record of at least 12 deliveries.

Form of zanjero's daily report used by the Azusa Irrigating Company.

AZUSA IRRIGATING COMPANY.

Zanjero's Daily Report.

———, 190—.

Run to—	Inches.		From—	To—	Number of hours.	Amount.		
	Day.	Night.						
			a. m. p. m. a. m.	a. m. p. m. a. m.				

——— ———, *Zanjero.*

The basis of water charges is a stream of 100 miner's inches running for twelve hours, the average price of such an amount being $3, the minimum $1.20, and the maximum $5.40, charged during July, August, and September. Night rates are but one-half day rates. The average charge per acre per year is about $10. Statements of account are sent out by the secretary on the first of each month, and a discount of 10 per cent is allowed for payment prior to the fifteenth.

The total cost of water delivery under this system is given as $1,940, or about 48 cents per acre. Of this, $1,040 is paid to the zanjero, $600 to the secretary for the work in connection with water charges, and $300 is for general office expenses.

THE MODESTO IRRIGATION DISTRICT.

About fifty irrigation districts were organized in California under the Wright irrigation district act of 1887, only a very few of which have been successful, the most prominent of these being the Modesto and the Turlock districts. These were two of the first districts organized, the author of the district law being a resident of the section included within the Modesto district. As finally organized the two districts comprise about 250,000 acres. The land was once a vast grain field, but is now being broken up rapidly into farms of 20, 40, and 80 acres. Every acre of land within the districts on which water can be run, whether town or farm property, is taxed to support the districts regardless of the quantity of water used. The two districts have practically the same requirements in connection with water delivery and practically the same obstacles to overcome. Therefore, what is said of the Modesto district is in general true of the Turlock district.

The total length of the Modesto Canal is 45 miles, and leading from it are eight laterals aggregating 81 miles in length. The main canal and these laterals cover 81,143 acres. The maximum flow in the main canal as constructed at present is 580 cubic feet per second, and in 1908 only 20,000 acres, or about one-fourth of the total area within the district was irrigated.[a] The district has been conceded a right to a continuous flow of 850 cubic feet per second at La Grange, and before many years the canal will be increased to that capacity. Alfalfa is the principal crop grown, but the areas devoted to orchards and vineyards have been greatly increased during the past few years.

The districts are operated under the Wright law, as amended in 1897, which has the following provision regarding the distribution of water:

> It is hereby expressly provided that all waters distributed for irrigation purposes shall be apportioned ratably to each landowner upon the basis of the ratio

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[a] The area irrigated in 1910 was 28,195 acres, but the amount of water run was no greater than in 1908.

Since 1908 the superintendent of Modesto district has made a number of changes in the plan of water delivery. He now distributes water to each of the eight main laterals in strict accordance with the area irrigated under each lateral, unless water is not needed. Another change is in the matter of records. Formerly receipts were taken from each irrigator for water delivery. These are no longer taken, but each ditch tender telephones to the office at Modesto daily reports of all deliveries, stating the irrigators being served, time service begins and ends, and crop irrigated. These reports are entered on cards and form a complete record of water delivery.

which the last assessment of such owner for district purposes within said district bears to the whole sum assessed upon the district: *Provided,* That any landowner may assign the right to the whole or any portion of the waters so apportioned to him.

This provision apparently gives a definite basis for water distribution within irrigation districts in California, but as a matter of fact no attention whatever is paid to it in the Modesto district, and it would be very difficult to do so. The law provides that landowners shall receive water in proportion to their district assessments, and that they shall have the right to assign their shares. The landowners include those who own town property within the districts, and the ownership of a business corner in Modesto carries with it a right to its pro rata of the entire water supply of the districts. A business corner has no need for irrigation, and in practice water is apportioned on the basis of the number of acres irrigated, no attention being paid to the assessments. As pointed out in a bulletin of this Office,[a] if the law and the present practice are not made to conform by changing one or the other, considerable confusion will arise when the owners of the non-irrigable but highly assessed property demand the water due them under the law, and the water becomes a subject for barter and sale—a condition which the very principle of district organization seeks to eliminate.

RULES AND REGULATIONS GOVERNING WATER DELIVERY.

The board of directors of the Modesto district has adopted a number of rules and regulations to govern water distribution, of which the following are a part:

(1) Between January 1 and March 1 of each year the ditch tender shall obtain from each user of water a written application, on blanks furnished by the district, specifying the number of acres he expects to irrigate, the kinds of crops, and the number and size of his diverting weirs, and upon such application it shall be the duty of the ditch tender to certify whether or not the applicant's weirs and ditches are in proper condition. * * * These applications, together with such certificate, shall be filed with the superintendent in the office of the district, and no water shall be furnished to any applicant until such application and certificate shall have been properly executed and filed.

(2) Each irrigator will be allowed not to exceed one hour [b] to irrigate an acre of land in alfalfa and other crops or land requiring flooding, but for trees, vines, and gardens the district will endeavor to supply a continuous flow, and in case of a scarcity of water, to provide rotation as often as possible; the time will start upon delivery of water to irrigator, and water must be used night or day continuously until time limit expires.

(3) Each irrigator shall be notified by the ditch tender at least twenty-four hours before the water will be delivered to him, and further notified of any

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[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 3.

[b] This time has since been changed to one-half hour and to twenty minutes in times of extreme low water.

change in the time of delivery, and the irrigator who has failed through any fault of his own to use water during an irrigation will not be entitled to any more water at any future irrigation than if he had used his full share at the time of allotment.

(4) The water shall be furnished in rotation to each irrigator (except by agreement between adjoining owners, satisfactory to the ditch tender, and which will not change the time of irrigation to other irrigators), commencing at the lower end of each lateral or distributing ditch. When a break occurs in any of the ditches, the party to whom the water is given until such break is repaired shall be allowed to finish before the water is taken from him, and shall not claim another irrigation for that run. When the ditch is repaired, the party using water at time of break shall have water returned to him to finish.

(5) Any person to whom water is offered from any ditch during the season must sign a receipt therefor. If the water is used, the receipt must show upon what kind of crop it was used; and if it is not used, the receipt must specify the reason. The object is to show the number of times water can be used should persons so desire, and also that it is not the fault of the district's officers that some people do not receive the water as often as others.

(6) The water will be apportioned to each lateral by the superintendent, and the ditch tenders will be in charge of the distribution of the same and will be held directly responsible by the superintendent.

(8) The district's employees alone will be allowed to open the discharge gates, and they have full authority to close the same as soon as the requisite amount of water for each irrigation has been discharged. Said gates will be supplied with locks, and the keys shall all be under control of the superintendent.

(11) Before water is furnished to any private distributing ditch the landowners receiving water therefrom must agree upon and sign rules and regulations satisfactory to the board of directors, providing for the repair, maintenance, and distibution of water from such ditch, authorizing some one of the signers to represent the users in all conferences with the ditch tender, and providing for the apportionment of the water, and that it shall be used in rotation, commencing at the lower end of such ditch and subject to all other rules and regulations of the district.

(15) Each ditch tender shall have full charge of his respective section and shall be responsible therefor. From his rulings and actions an appeal may be made to the superintendent, which may be filed in writing with the secretary for him. From the action of the superintendent appeal may be made to the board of directors by anyone who considers himself aggrieved.

Perhaps the most noteworthy of the above rules is No. 15. This is the only instance encountered in which a canal superintendent is not directly responsible for water delivery. During the past season the superintendent has questioned the advisability of retaining this rule, and has recommended that he be made responsible in theory as well as in fact, as he is required by circumstances to direct delivery personally, in large measure.[a] The applications as provided for in rule No. 1 are taken on forms bound in small books convenient for the ditch tenders in taking and for the office in filing. The head allowed in practice under rule 2 is 10 to 20 cubic feet per second for alfalfa and 0.5 to 1 cubic foot per second for orchards and vineyards. The custom has been to run a continuous stream for orchards, vineyards, and gardens, but the superintendent aims to put all crops on an "alfalfa" basis; that is, to deliver to all crops on a time basis, with the number of hours per acre varying with the needs of the different crops. Rule 4 was intended, doubtless, to insure the lower irrigator as good service as the irrigator above. It met with the practical difficulty, however, that the water not taken by the lower user for any reason was wasted, and the superintendent had to reverse the practice. Delivery now begins at the heads of the laterals. The receipts provided for in rule 5 are taken in duplicate, the stubs being retained by the ditch tenders and the originals forwarded to the office at Modesto. Their value has been considerably lessened, as no satisfactory way has been found for filing them. No records of delivery are kept, and under the system there is no way of getting any complete records of delivery, such as are considered so valuable on many systems.

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[a] Since this was written the rules have been changed to give the superintendent complete control of water distribution and delivery.

The main laterals are so arranged that at present most irrigators receive water directly from them in their own private ditches. A number of colony tracts, divided into small holdings, have been opened, however, and these require a large single lateral leading from a main district lateral to supply them. It is for delivery on such laterals that rule No. 11 provides. The independent delivery contemplated by the rule for these laterals has not proved satisfactory, the irrigators seeming to prefer delivery by the district ditch tender rather than by one of their own appointment. Consequently, the district has recently begun to take over these laterals and manage them exactly as its own main laterals.

Following out the apparent intent of rule No. 15, each ditch tender follows his own notion, resulting in numerous plans. One aims to deliver water from any section of his lateral practically on demand, so long as a user receives no more of his share; another delivers in runs, supplying water to one user after another, beginning at the upper end of his lateral, insisting that each user take water in his turn or not at all; and a third delivers in runs, but is less particular about a strict enforcement of turns, allowing a user to make up in one run what he did not care to take during a preceding run.[a]

MEASUREMENTS AND EXPENSES.

No measurements are now made at any point in the district except at the head of the canal at La Grange. There frequent current-meter ratings are made and daily gage readings are taken and telephoned to the office at Modesto. When there is a flow of more than 300 cubic feet per second in the canal the superintendent keeps water flowing continuously in all of the laterals, the amounts in each carrying from 20 to 200 cubic feet per second in the main laterals and 10 to 25 cubic feet per second in the private laterals supplying communities of irrigators. When the supply falls below 300 cubic feet per second it is " bunched " and run in only two or three laterals at a time and in strict rotation.

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[a] Since this was written the plan of delivery in strict rotation on all the laterals has been adopted.

This district is well covered by telephone lines, there being an aggregate of 110 miles already constructed. Of the total, the district owns a 35-mile line from Modesto to La Grange, and has subsidized farmers' lines, aggregating 75 miles in length, at $15 to $75 per line, having paid $490 in subsidies, which are given in consideration of the free use of the lines by the district officers and employees, without any obligation on the part of the district to pay any of the cost of maintenance. Additional farmers' lines will be subsidized until the entire district is covered. The cost to the district for construction and maintenance of the 35-mile line to La Grange averaged about $100 per mile.

The cost of water delivery for 1907 is given by the secretary of the district as approximately $8,000, or about 40 cents per acre for the 20,000 acres irrigated. This included the salary of the engineer and superintendent for eight months at $125 per month, the salaries of the 15 ditch tenders for the same period, and the printing of receipt and application forms. Nothing was included for the secretary, as the time devoted by him to delivery balanced the time spent by the superintendent in maintenance. The ditch tenders start at $60 per month each, and are increased to $65 the second year, $70 the third and fourth years, and $75 after they have begun the fifth year of service. The district furnishes no conveyances, and where a horse is furnished, $5 per month is deducted from the salary. In 1904 $50 per month was paid, with $10 per month added when a conveyance was needed.

SYSTEMS USED ON TYPICAL CANALS IN COLORADO.

THE NORTH POUDRE CANAL.

This canal system is composed of the North Poudre Canal and 20 reservoirs and covers a large tract of land north of Fort Collins, Colo. It is controlled by the North Poudre Irrigation Company and the water supply is derived from Cache la Poudre River and Box Elder, Coal, and Park creeks. The main North Poudre Canal in 25 miles long and leading from it are 140 miles of main laterals. The total acreage irrigated is 27,500, of which 7,000 was in alfalfa in 1908, 18,000 in grain, and 2,500 acres in sugar beets. The maximum flow in the main canal is 210 cubic feet per second. A large part of the supply is stored in the reservoirs during periods of high water and later either run from the reservoirs into the company's ditches or exchanged with other systems for water directly from the river. There are 500 stockholders in the company and approximately the same number of irrigators. The land under the system was sold to the irrigators with 25 shares of stock in the company for each 80 acres, there being 8,000 shares and 320 80-acre rights.

PLAN OF DELIVERY.

Water delivery is in charge of a superintendent with headquarters at Wellington, near the center of the system. In 1908 seven canal riders were employed. The period of service of the canal riders is limited to the irrigation season, April to September, but they are employed subsequent seasons if they have proved satisfactory. Each canal rider is provided with a horse and cart, and covers 25 to 30 miles of ditch each day.

Water is kept in the canals constantly during the irrigation season and is delivered to the irrigators practically on demand. At the beginning of each season the superintendent estimates the total supply likely to be available, being careful to make his estimate conservative, and determines the quantity that can be delivered for each share in the company. This is comparatively easy, as the greater part of the water is stored in the reservoirs, which have been surveyed to show the capacities at various depths. In years of normal stream flow the apportionment per share is about 200,000 cubic feet, or about 4.6 acre-feet. In 1908 the apportionment was only one-half of this amount. The canal rider is provided with a complete list of the shareholders on his division, showing which, if any, are delinquent in assessments, as such delinquents are not allowed to receive water. When a shareholder wishes water he notifies the superintendent, who instructs the canal riders to make the deliveries ordered. No stated size of stream is adhered to, it being the policy of the management to give as large a head as the available supply and the number of irrigators from one lateral will permit. The system has public telephone connection with nearly every farmhouse.

Water is delivered over rectanglar weirs having crest lengths of 1, 1.5, 2, 3, 4, 5, and 6 feet, depending upon the amount to be run. The discharge over the weirs is regulated by iron headgates, a sketch of which is shown in figure 5. These are set in concrete in the canal bank, fastened to the upstream ends of the tile-pipe outlets, and arranged so that they can be locked readily either to prevent any change or to permit it only within certain limits. These gates are supplied f. o. b. Fort Collins, at $14 to $38, to fit tile from 6 to 24 inches in diameter.

Each canal rider is provided with a table of discharges over standard rectangular weirs, with two complete end contractions, and a table of corrections to be made where there are no end contractions. The weir tables show the discharge in cubic feet per second, Colorado statute inches, cubic feet per hour, and cubic feet per twenty-four hours. The unit used is the usual Colorado inch, of which 38.4 are equal to 1 cubic foot per second, while the flow in the main canal and laterals is usually reckoned in cubic feet per second. These detailed tables enable the canal riders to make accurate deliveries with little difficulty. Each rider is provided with a record book in which a complete record of deliveries is kept. This book provides one page for each irrigator and shows the number and size of weir over which water has been delivered, the date of delivery, depth over the crest of the weir, discharge in cubic feet per second, hours run, and the total number of cubic feet run. A space is provided to show the total amount in cubic feet per second of water delivered to the irrigator up to the end of delivery. This book contains also a table of equivalents of the standard units of measurement by means of which the rider can readily convert one unit into another. The riders send to the superintendent each day written reports from this book, showing the amount of water run to each user. The following is a copy of the report of one canal rider for one day, and of a page in the field book, showing the form and value of these reports.

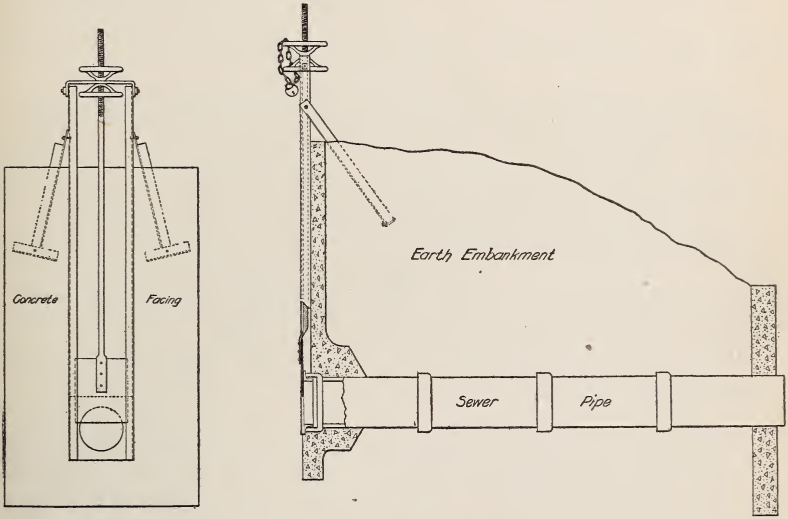

FIG. 5.—Iron gates used at heads of laterals by the North Poudre Irrigation Company.

Copy of daily report of canal rider of the North Poudre Irrigation Company.

Water delivered by the North Poudre Irrigation Company June 20, 1907.

To—	Over weir No.	Size weir.	Depth.	Hours run.	Amount.	Remarks.
			Inches.		*Cubic feet.*	
J. D. Dunbauld		24	5	24	147,880	(Here is given description of holdings.)
W. A. Richard		24	4¾	24	138,552	
J. T. Wright		24	5½	24	170,371	
Z. Hughes		24	4¾	24	138,552	
G. C. Ritter		24	5¼	9	63,882	
George Palmer		24	4¾	24	138,552	
G. S. Pintler		24	5½	24	170,371	
W. L. Sivers		24	5½	24	160,056	
George O. Dodge		24	4½	24	127,180	
L. Francis		24	5½	24	160,056	
R. L. Shrader, rate box.			[a]1.3	24	120,960	

[a] Feet.

Measured by I. G. GOODING, *Canal Rider.*

Sample page from field book of canal rider of the North Poudre Irrigation Company.

WATER DELIVERED BY THE NORTH POUDRE IRRIGATION COMPANY.

To Edson Waddle.

No. of weir 40 Size weir 24 Rate box ______.

Date.	Depth.	Cubic feet per hour.	Hours run.	Amount.	Remarks.
June 24	3	2,921	5	14,610	
June 25	4	4,460	24	107,056	
June 26	4	4,460	24	107,056	Part of east ½ of 29-9-68.
June 27	4	4,460	24	107,056	
June 28	4	4,460	24	107,056	

Total to June 28, 1908=442,834 cubic feet.
Posted on page 67.

In addition to the record books and the daily reports of delivery just described, a complete ledger is kept in the superintendent's office showing the delivery to each irrigator throughout the season. The pages in this ledger provide space for each day during the months of April to September, inclusive, and show for each irrigator and for each run not only the number of the weir, its size, the depth over crest, the hours run and amount run, but also the kind of crop irrigated.

The total cost of water delivery under the system is given as $4,475, or about 16 cents per acre, of which $1,200 is the salary of the superintendent, $3,000 the total salaries of the canal riders, who receive $75 per month each after satisfactory service, and $275 the office expense properly chargeable to delivery.

THE LARIMER COUNTY CANAL.

The Larimer County Canal is controlled by the Water Supply and Storage Company. It has a comparatively late priority on the water of the Cache la Poudre River and depends on stored water and streams outside of the basin of the Cache la Poudre River. Its present supply comes from Cache la Poudre, Grand, and Laramie rivers, and Michigan Creek, the Grand being on the western slope of the Rockies and Michigan Creek and Laramie River being tributaries to the North Platte. The main canal is 72 miles long and has 78 miles of distributing laterals. The acreage irrigated in 1907 was 36,700, consisting of 1,500 in orchard, 8,000 in alfalfa, 15,000 in grain, 2,700 in sugar beets, 6,800 in potatoes and 2,000 acres in native grasses. The maximum flow in the main channel is 600 cubic feet per second and the average about 250 cubic feet per second. The length of the 23 laterals varies from 0.5 mile to 20 miles. Of the 600 shares of stock 496 have been issued and are held by 270 water users, each holding one-fourth to 24 shares.

PLAN OF DELIVERY.

Water delivery under this system is under the direct control of the president of the company, who acts as superintendent and has six ditch riders under him. The first rider is located at the headgates, about 7 miles above Fort Collins, attends to the headgates, and rides the first 6 miles of the canal; the second and third tend 15 miles of canal each, and the others 12 miles each.

The distribution of water among the ditches in Colorado is under public authority. Each stream usually comprises a water district within which water distribution is controlled by a water commissioner acting under the direction of the division engineer, who in turn is under the state engineer. The water commissioner on the Cache la Poudre River receives telephone messages every evening from observers at Chambers Lake, a large storage reservoir near the summit of the Rocky Mountains owned by the company, and from Grand River Ditch, as to the amount of water the Water Supply and Storage Company is turning into the Cache la Poudre River. On the following day the company is permitted to divert this amount into its canal less an allowance for seepage and evaporation losses, together with any water that may be due directly from Cache la Poudre River on the company's priorities. As soon as the headgate attendant on the Larimer County Canal receives notice from the water commissioner as to the amount of water the canal will be allowed to divert, he notifies the superintendent and the ditch riders.[a]

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[a] Outside of Chambers Lake the principal reservoirs of the Water Supply and Storage Company are situated below the inlet of Larimer County Canal and the water stored in them must therefore be used by exchange with canals lower down the river which are entitled to receive water from the river. During times of such exchange the Water Supply and Storage Company must

and this report forms the basis for water delivery on the following day, when the superintendent or the headgate attendant notifies the ditch riders of the amount of water to be delivered for each share of stock and the ditch riders set and lock the gates at the heads of the 148 laterals leading from the main canals in order to give each the share to which it is entitled. On some of the laterals 20 or more farmers receive water from a single headgate, the water being divided usually by a special ditch rider employed by the farmers. If for any reason a farmer does not care for water he informs the ditch rider on the main canal or the lateral.

When a ditch rider on the main canal sets and locks the headgates, he deposits in a metal case hanging on the gate a small card showing the number of shares held by the users, the number of inches allowed for each share during the current day, and the depth over the weir necessary to give that amount. This card remains in the box until replaced by one for the following day, thus enabling any irrigator under the lateral to ascertain at any time if he is receiving his proper allowance. The water is measured to the various laterals over wooden rectangular weirs set short distances below the lateral headgates, and having crest lengths of 1 to 6 feet, depending upon the amount of water to be delivered. The flow is regulated by iron headgates similar to those used on the North Poudre system (fig. 5, p. 39).

Section 8 of the by-laws of the company governing the distribution of water is given in full below. The provisions are general and show merely the powers of the company in reference to distribution and the requirements for receiving water:

> Any water supplied by this company, which is delivered or caused to flow into the Larimer County Ditch, either from the reservoirs of this company or from any other sources provided by this company, shall be under the control of this company, subject to any contract to protect the rights of the Larimer County Ditch Company in the control of the canal, and shall be distributed pro rata among the stockholders of this company who shall then own and control water rights in the Larimer County Ditch, who shall from time to time be entitled to the same, or their lessees, agents, or other representatives.
>
> In order for a water-right owner in the Larimer County Ditch Company to be entitled to receive water distributed by this company, he must have stock in this company, with all assessments paid, to the extent of one share of stock for every water right upon which he receives water.

RECORDS AND EXPENSES.

Each ditch rider is provided with a record book, of which sample pages are here shown. Each page provides for the record for two

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also await notice from the water commissioner before making diversions on account of the exchanged water. For a full account of the interesting system of exchanges used on Cache la Poudre and Big Thompson rivers, Colorado, see U. S. Dept. Agr., Office Expt. Stas. Buls. 134 and 218.

weeks. At the close of each season these books are filed in the office of the company, and new books are issued at the beginning of the following season:

Sample pages from record book of ditch rider of the Water Supply and Storage Company.

RECORD OF WATER DELIVERED IN FIRST DIVISION OF CANAL OF THE WATER SUPPLY AND STORAGE COMPANY.

Name.	No. of gate.	Size of weir.	Inches per share.	Week ending August 6, 1904.							Week ending August 13, 1904.						
				S.	M.	T.	W.	T.	F.	S.	S.	M.	T.	W.	T.	F.	S.
				10.	10.	15.	15.	15.	15.	15.	12.	12.	15.	15.	10.	10.	10.
Golding Duyre .	3	24	Number of rights.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
			Inches in depth.	$\frac{5}{8}$	$\frac{7}{8}$	....	....	....	....	....	$\frac{6}{8}$	....	$\frac{7}{8}$	....	$\frac{5}{8}$	....	....
Geo. Stanley....	7	24	Number of rights.	1	1	1	1	1	1	1	1	1	1	1	1	1	1
			Inches in depth.	$1\frac{1}{16}$	$1\frac{5}{8}$	....	....	....	....	....	$1\frac{1}{4}$	....	$1\frac{3}{8}$	....	$1\frac{1}{16}$	....	....
Mrs. C. P. Miller.	10	24	Number of rights.	1	1	1	1	1	1	1	1	1	1	1	1	1	1
			Inches in depth.	$1\frac{3}{16}$	$1\frac{5}{8}$	....	....	....	....	....	....	....	....	....	....	....	....

The ditch riders are also provided with weir tables, showing the depths of water to be run over weirs of the various sizes for each share or fraction thereof of stock in the company. These tables are based on the delivery of 0.667 cubic foot per second per share, which is equivalent to 26 statute inches, or 40 " farmer's " inches, the usual measure in water delivery. No computations are necessary on the part of the ditch riders other than to make proratings when the supply being delivered is below the 40 farmer's inches per right, on which the tables are based. When prorating it is necessary only to multiply the number of inches being given to the right by the number of rights to go through the weir and divide by 40. The quotient is the number of full rights, and from the table the corresponding depth on the weir is found.

A complete record is kept in the office of the company at Fort Collins of the amount of water in each reservoir of the system, the daily withdrawals from each, and the daily flow both in the mountain supply ditches and in the main canal. The measurements in the main canal are made over a weir 2,000 feet below the headgates, where a recording apparatus is kept. Books have been printed especially for these records, each page of which has space for a complete record of the daily operations and conditions at the water source for one month. The following is a copy of a portion of the water-ledger page for July, 1908.

Sample page from water ledger of the Water Supply and Storage Company.

THE WATER SUPPLY AND STORAGE COMPANY.

Record of weir measurements and discharge of ditches and record of water stored in reservoirs during the month of July, 1908.

Larimer County ditch.					Laramie River Ditch.				Depth in feet.									Grand River ditch (cubic feet per second).
Day of month.	Depth in feet.			Total discharge (cubic feet per second).	Depth in feet.			Total discharge (cubic feet per second).	Reservoir No. 1.	Reservoir No. 2.	Reservoir No. 3.	Reservoir No. 4.	Reservoir No. 5.	Lindenmeir Lake.	Richards Lake.	Black Hollow Reservoir.	Curtis Lake.	
	6 a. m.	12 m.	6 p. m.		6 a. m.	12 m.	6 p. m.											
1	3.2	3.2	3.2	301	....	2.21	....	115	28–0	2–0	2–0	16–0	27–0	8–0	18–6	23–0	12–6	103.4
2	3.1	3.1	3.1	228	....	2.2	....	114	....	....	....	....	....	....	....	......	2.89	102.72
3	3.1	3.1	3.1	228	....	2.16	....	110	27–4	2–0	2–0	18–4	27–6	8–0	18–2	22–10	12.6	100
4	3.1	3.3	3.3	329	....	2.16	....	110	....	....	....	....	....	....	....	......	....	....
5	3.3	3.3	3.3	329	....	2.19	....	113	....	....	....	....	....	....	....	......	2.92 2.49	104.8 109.7
6	3.4	3.4	3.4	329	....	2.19	....	113	....	....	....	....	....	....	....	......	2.92	104.8
28	2.3	2.3	2.3	179	....	1.7	....	68.5	....	....	....	....	....	....	....	......	1.97	45.96
29	1.6	1.6	1.6	118	....	1.71	....	69.28	....	....	....	....	....	....	....	......	1.92	43.56
30	3.5	4.5	4.5	343 487	...	1.82	....	77.96	29–0	....	....	15–0	29–0	8–6	18–0	24–0	2.19 15–0	57.06
31	4.1	2.3	2.3	428 194.5	...	1.92	....	86.28	29–0	....	....	15–0	30–0	8–6	18–0	25–0	2.26 15–0	60.96

The Water Supply and Storage Company has built about 45 miles of telephone line, at a cost of $7,000, extending only to the source of supply near the summit of the Rockies. The total cost of delivery under this system is estimated at $6,230, or about 17 cents per acre per year. This includes $750 of the salary of the president and superintendent, $5,000 for the ditch riders, who receive $3 per day each when employed, and $480 for office expenses. The salaries of the ditch riders include those paid to two men at Chambers Lake and on the Grand River Ditch, who receive $2.50 and $3 per day, respectively, and that paid to the headgate man on the main canal, who receives $100 per month and house rent.

THE CONSOLIDATED HOME SUPPLY SYSTEM.

The system of water delivery followed by the Consolidated Home Supply Ditch and Reservoir Company near Loveland is similar to that of the Water Supply and Storage Company, since this company depends chiefly on stored water during the entire season and entirely on it during the periods when water is most needed. This system consists of the Home Supply Canal, the Lone Tree and Mariana reservoirs, and the Home Supply reservoir ditch. The Home Supply Canal is the inlet for the Lone Tree reservoir and the direct source of supply for a portion of the land. Water is delivered to the rest of the land through the Home Supply reservoir ditch, which is the outlet of the Lone Tree reservoir. The Mariana reservoir, being below both the main canal and reservoir ditch, water stored in it is exchanged for river water.[a] The main Home Supply Canal and the reservoir ditch together have a total length of 28 miles and the laterals leading from them aggregate 12 miles in length. The combined capacities of the two reservoirs is about 590,000,000 cubic feet. The maximum flow in the main canal is 285 cubic feet per second, and the average when water is being run is about 225 cubic feet per second. The principal crop irrigated is sugar beets, and three irrigations are given. The largest acreage is in grain, 17,500 acres having been irrigated in 1908, 6,000 in alfalfa, 200 in potatoes, and 100 in native grasses. There are 179 irrigators who own the 2,000 shares of stock that have been issued.

PLAN OF DELIVERY.

Water delivery under this system is in charge of a superintendent, who has two ditch riders under him. At the beginning of each irrigation season (in April) the total amount of water stored in the reservoir is ascertained and a determination made of the number of days a 5-inch flow can be run for each share. A series of runs is made during the season and each user is allowed to receive water on demand during any run, provided he receives it for full-day periods and in quantities of not less than 5 inches.[b] In other words, he has in the reservoirs a definite quantity of water which he may draw on as freely as a depositor can draw on his funds in a bank, within reasonable limits of time and quantity. It is not necessary to regulate the amount he wishes nor the time he irrigates with any reference to irrigation by his neighbors. The farms are all comparatively close to the reservoirs, no long laterals are required, and there is little waste in delivering to one or two users. If any water remains at the end of the run a second run is given. Water in the Big Thompson is highest during May and June, making it possible to refill the reservoirs after the first part of the irrigation is completed. It happens sometimes that after the reservoirs have been refilled there is still a surplus in the river above the amount necessary to supply the canals having earlier priorities than the Home Supply system, when the irrigators under this system are then supplied "free" water directly from the river and no account is kept of it. In the latter part of June, 1908, a run of twenty-eight days was first made, this being the estimate of the superintendent for the season. Each shareholder was entitled to one hundred and forty 24-hour inches, to be drawn as desired. Later on it was found that a surplus would remain, and the length of the run was increased, first to thirty and then to thirty-one days. The supply for that year was below normal, the usual seasonal run being about forty days.

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[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 134.

[b] The inch used on this system is not the statute inch of Colorado—0.026 cubic foot per second—but 0.018 cubic foot per second.

The superintendent of the Home Supply system has connection at his residence with the two local telephone lines, which cover the entire system, and receives calls for water from the farmers both morning and evening. Orders for turning the water on or off are given the ditch riders by the superintendent. The ditch rider in the upper division covers about 12 miles of canal and the one in the lower division about 15 miles. When any irrigator has drawn his full amount for any one run his headgate is locked securely and not opened again during the season unless an extra run is made.

Throughout this system Cipolletti weirs are used for measuring water to the farmers. Each ditch rider is supplied with a weir table and is instructed to make careful measurements. The flow over the weirs is regulated by steel gates similar to those on the North Poudre and Larimer County canals (fig. 5, p. 39). The facing of the headgate is usually of concrete, but sometimes of planking. On some portions of the system the ordinary undershot wooden headgates are used, placed at the upper end of a wooden box, but these are being displaced rapidly by the steel gates.

RECORDS AND EXPENSES.

The only permanent record of delivery kept is the superintendent's book, which shows the size of stream delivered to each water user and the days on which he receives it.

The plan followed by the ditch riders in keeping their records leaves little chance for mistake. As the orders are received each day from the irrigators their names, with the number of shares wanted and length of time to be run, are noted on cards for that day. Multiplying the number of shares wanted by 5 gives the number of inches to be run. These cards are taken by the ditch riders and the orders for turning the water on or off are carried out. The ditch riders make entry of all water being drawn throughout their respective beats and this record is copied into the superintendent's book, the names and amounts being checked off as this is done.

The superintendent of the Home Supply system receives a salary of $1,000 per year and the two ditch riders each receive an average of $2.50 per day, being paid more in the irrigating season and less in the winter. Allowing $800 for additional help at the headgates and on the ditches and $500 for office expenses, the amount charged to water delivery is $4,100 per year, or about 15 cents per acre. Part of this, however, should be charged to maintenance, as the superintendent and ditch riders devote their time in the winter to making repairs.

THE ROCKYFORD CANAL.

Sixteen ditches in the vicinity of Rockyford have substantially the same plan of delivery. The following description of the plan used on the Rockyford Canal will apply to the others:

The Rockyford Canal takes practically a uniform stream of 112 cubic feet per second from the Arkansas River through April, May, June, and a part of July. This water passes to about 200 irrigators through 16 miles of main canal and 95 miles of principal laterals. Some 10,000 acres are irrigated, consisting of about equal areas of alfalfa, grain, and sugar beets. Only one man is employed in water delivery. He lives at the headgate, the house being furnished by the company, and divides the supply to the laterals throughout the system. One man is able to do this work owing to the steady and uniform flow in the canal, his chief duties being to keep the gates and the canal free from obstructions after the lateral gates are properly set, the farmers themselves dividing the water after it is turned into the laterals. A record of the flow into the canal at the headgate only is kept.

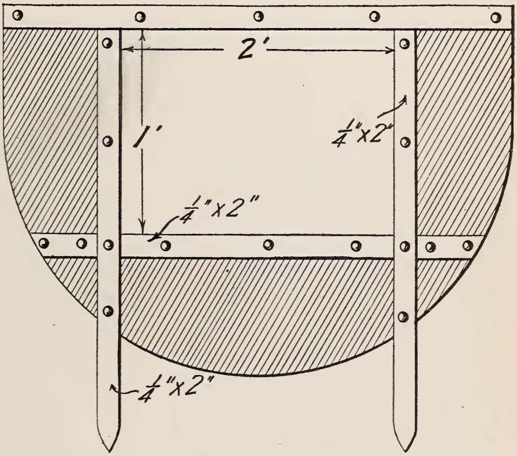

Fig. 6.—Portable galvanized-iron weir used on the Rockyford Canal.

According to the by-laws of the Rockyford Ditch Company, water is to be prorated among the users in proportion to the number of shares held by each, but "the company shall not, and does not, guarantee to the holders of stock the use at all times of the full amount of water they are respectively entitled to," but "in order that the water may be equitably distributed among the stockholders, the directors and the persons intrusted by them with the management of the ditch are empowered to rotate water among consumers, or to divide the ditch into districts for the distribution of water, or to adopt such other methods as in their judgment may from time to time become necessary to secure to all stockholders their proportionate share of water." The steady flow in the canal seems to render rotating unnecessary and the usual practice is to deliver individual streams to the various users.

The ditch rider is supplied with a galvanized-iron portable rectangular weir, of which a sketch is shown in figure 6. It is braced with $\frac{1}{4}$ by 2 inch iron straps, the vertical braces extending below the galvanized-iron sheet to serve as feet. The crest is 2 feet long. When the ditch rider wishes to set a lateral gate he closes it and selects a suitable place in the lateral to set the weir. After setting the weir and leveling it by admitting a small stream, he opens the gate so that the required amount of water will flow over the weir. Where two or more irrigators take water from the same lateral, division is made by means of a simple flume, into which the water falls and is divided by a board 6 inches high dividing the flume, proportionally to the number of shares the irrigators are to receive.

The ditch rider on the Rockyford Canal receives $75 per month when employed and the total annual expenses chargeable to water delivery are $800, or 8 cents per acre.

SYSTEMS USED ON TYPICAL CANALS IN WYOMING, MONTANA, AND IDAHO.

THE WHEATLAND CANAL.

The Wyoming Development Company's canal system at Wheatland, Wyo., is the largest system outside of government works in southeastern Wyoming, and is typical of irrigation canals in that portion of the Rocky Mountains where grain and alfalfa are the principal crops irrigated. The water supply comes from the Laramie River through three principal canals, canals 1 and 2 leading to the irrigated fields and canal No. 3 being a reservoir supply ditch. The total length of the three main canals is 54 miles and the aggregate length of the laterals leading from them is 100 miles. The total area irrigated in 1908 was estimated at 30,245 acres, of which 10,000 acres was in alfalfa and 19,500 in grain. The maximum flow in canals 1 and 2 is 700 cubic feet per second, and the average 440 cubic feet per second. Three hundred and fifty irrigators receive water from the system. Water rights, or shares, in the canal system were sold to the settlers as an inseparable part of the land purchased, on the basis of 1 cubic foot per second continuous flow for each 80 acres. Each irrigator is entitled, consequently, to receive water in proportion to his land area.

Water delivery is in charge of a general superintendent, the work being performed by 5 ditch riders, each of whom has charge of 5 to 10 miles of main canal and the laterals leading from it in his section. The water supply of the system at present is much more than is needed, and as a consequence it has not been necessary to perfect a plan of water delivery. Water is delivered in continuous flow at the rate of about 1.5 cubic feet per second for each 80 acres irrigated. A continuous flow of 1 cubic foot per second for each 70 acres is the maximum amount for which a water right can accrue under the

Wyoming law, but this limit is not enforced in actual water distribution unless the failure to do so would deprive some regularly adjudicated priority of its share. Each ditch rider receives the proportional part of the entire flow due to irrigators served by him and distributes it in accordance with the shares owned by each. In some cases the ditch riders make delivery to the individual users and in others only to the laterals, leaving the individual deliveries under such laterals to be made by the users themselves.

Each lateral has an organization subsidiary to the main canal company, which owns and controls both the laterals and sublaterals. These lateral organizations are independent of the main company except in case of disagreement, when the advice of the general superintendent is relied upon to straighten out the tangle. At the beginning of the season each lateral organization selects one of its members to act as ditch boss, whose duty it is to oversee the cleaning and repair of the lateral and its branches, to put dividing boxes and weirs in proper condition and adjustment, and to see that each irrigator receives his share of water. All expenses connected with both construction and maintenance of these laterals are borne by the lateral companies, and when a new farmer comes in he is required to pay into the treasury his share of the cost of construction.

The only regular and continuous water measurements taken on the system are at the headgates of the main canals. Records of these are preserved in the office of the company. The only devices in use in measuring water to the farmers are flumes 8 to 10 feet long, with weirs across them 12 to 15 inches high, made by the farmers. Accurate measurements are not attempted, and the measuring devices afford no suggestion to other systems. Streams are subdivided with flumes divided into longitudinal compartments having uniform weirs and proportional in width to the share of water each should receive.

No written rules and regulations governing the delivery of water are in force, and no form of application for water is used, each irrigator usually leaving a note at the headgate of his lateral whenever he desires water to be turned to him. A telephone line costing about $500 and covering practically the entire system has been constructed. The canal company owns shares in this telephone line.

The total cost of water delivery under the system is given as $3,200 per year, or only about 11 cents per acre. This is made up of $1,200 as part of the salary of the general manager and superintendent, $1,700 paid to ditch riders from April 15 to September 15 at $65 per month each, and $300 for office expenses.

THE FARMERS' CANAL COMPANY.

A typical irrigating canal of Montana is that of the Farmers' Canal Company at Bozeman, which receives water from the West

Gallatin River and supplies 15,000 acres of grain, clover, alfalfa, and potatoes. The main canal is 15 miles long, with a maximum capacity of 300 cubic feet per second and distributaries aggregating 25 miles in length. The company is a cooperative organization of 60 irrigators. The by-laws provide for two series of stock, each share of the first series entitling the holder to the use of $89\frac{2}{7}$ inches of water and each of the second series to a continuous flow of $61\frac{1}{2}\frac{7}{8}$ inches. Each irrigator usually owns one share of each series. The company is not concerned with water delivery after the water has been turned into the laterals. A canal walker is employed for two months, from June 10 to August 10, at a salary usually of $90 per month, to patrol the ditch banks and divide the water between the laterals. He is subject to instructions from the president of the company, who has full charge of water delivery and receives $1.50 per day for each day actually spent on the canal, averaging about $40 per year. A superintendent is employed also at $4.50 per day whenever repair work is necessary.

Water is delivered in a continuous flow, if desired in that way by the irrigator. The president and canal walker only have authority to make or permit changes in the headgates. Tampering with the gates, except when it is necessary to repair breaks or to avert damage, is subject to a fine of $50. This penalty was enforced once, since which time there has been no trouble. In case of a surplus or a scarcity each irrigator receives his proportion of the total supply available, and handles an average of about 100 miner's inches, or 2.5 cubic feet per second, as an irrigating head, and in exceptional cases irrigators have been known to use as much as 200 inches, or 5 cubic feet per second.

A Cipolletti weir has been placed 20 to 30 feet below the headgate of each lateral or farmer's ditch. The regulating gates are substantially constructed and the canal walker is able to run the amount required over the weirs with little difficulty. It is the opinion of a local observer that the secret of success lies in the use of the weirs, good headgates, and the division of the water by a disinterested canal walker. No records are kept of the delivery to the various irrigators. If the irrigators desire water when it is not running in their ditches, they make application to the canal walker. The management contemplates providing for written notices when it is desired to have water turned on or shut off.

The cost of delivery under this system is less than that under any system considered in this report, being only 1.5 cents per acre per year. This low cost is due to the fact that the regular irrigating season lasts only two months, that only general farm crops are grown, that no attempt is made to control delivery except from the main canal, and that no records are kept.

THE NAMPA-MERIDIAN IRRIGATION DISTRICT.

Water delivery in the Nampa-Meridian Irrigation District, in Idaho, is under the control of a managing director, who receives $3 per day for the time employed. He has under him a foreman or overseer at $125 per month, a headgate man at $75 per month, a night headgate man at $60 per month, and eleven ditch riders at $65 per month. The main canal is 50 miles in length and there are 114 miles of principal laterals. Each ditch rider covers about 15 miles of canal every day. The average flow in the canals is 470 cubic feet per second, and 1,000 irrigators are supplied. Each irrigator is given a continuous flow for the length of time desired, the size of stream depending upon his water right or the amount applied for.

At each point of delivery from the main canal the company maintains a small box in which the irrigators place their applications for water. The ditch rider, after looking over these orders and adjusting the flow to supply them, places a card in the box stating the amount passing over the weir and for whom it is intended. A private telephone line covers the entire system. At 7 o'clock each morning the ditch riders report the stage of water in the various portions of the main canal and laterals to the foreman and receive orders regarding changes during the day. Below is given the form used for making applications for water:

Form used for making application for water from the Nampa-Meridian irrigation district.

TO CUSTOMERS.

Please deposit this card in the lateral lock box.

N-M Irrigation Dist.
Date ....1908.
Turn water in..
Lateral No..on
(Date)..and
until further notice, as follows:
..............................., *Water Master.*

FOR ACCT. OF—	Inches.
....	....
....	....
....	....
....	....
....	....

SYSTEMS USED ON TYPICAL CANALS IN UTAH.

THE BEAR RIVER CANAL.

The Bear River Canal, in the north-central part of Utah, is the most extensive and important feature in the irrigation of Bear Valley lands and the largest system in the State. The land covered by it was originally a ranch of 125,000 acres lying on both sides of the Bear River in the vicinities of Corinne, Bear River City, and Garland. The project was completed in 1894 at a reported cost of $2,000,000. During the first nine years the canal passed through the hands of receivers three times, and in 1903 was bought by the Utah Sugar Company for $350,000, and has been operated successfully by them. The system comprises two main canals, West Side and East Side canals, the latter supplying only a small acreage, as 500 cubic feet per second is used for power. The maximum flow in the West Side Canal is 565 cubic feet per second and the average flow 385 cubic feet per second. In 1908, 34,000 acres were irrigated, 7,500 of which were in alfalfa, 15,000 in grain, 4,800 in sugar beets, and 800 in orchards. This canal is 49 miles long and has 50 miles of principal laterals owned by the company and about 100 miles of laterals leading from it owned by the consumers. Water is delivered under 1,200 contracts.

PLAN OF DELIVERY.

The same force attends to both water delivery and maintenance. The chief engineer receives a salary of $3,000 per annum, with residence, light, teams, and traveling expenses when away from home and under him are a general foreman at $90 per month, an assistant foreman at $75 per month, six ditch riders at $75 per month during the irrigation season, and four cleaning gangs. Delivery is directly under the charge of the general foreman, to whom the ditch riders report. The ditch riders are assigned to the same divisions year after year and are thoroughly familiar with their work and with the farmers with whom they have to deal. Each ditch rider controls about 10 miles of canal, and in addition to the work of delivery is responsible for the condition of the canal in his division and is expected to keep the chief engineer and general foreman thoroughly informed on all matters of importance. All disputes between the ditch riders and the farmers regarding the delivery of water are referred to the general foreman or the chief engineer. The chief engineer writes regarding the ditch riders:

> They are married and own farms in the districts which they operate. They are cool-headed men who do not assume a high and mighty attitude with the farmers. They are instructed to work for the best interests of the water users as well as for the company and at no time to abuse the water users in case of disputes.

The water delivery is in general governed by sections 11 and 12 of the terms and conditions of sale of water made a part of the contract between the Utah Sugar Company and the individual water users. Section 11 and the essential part of section 12 are as follows:

> SEC. 11. That the use of water contracted for shall be governed and regulated by the company; and the latter may from time to time either allot to the consumer certain hours for the use of water (of which allotments it shall cause him to be duly notified), or, at its option, may give the consumer a continuous flow. That the consumer shall use the water furnished him carefully and without waste. That all gates, weirs, or other devices for the distribution of water on the company's canal and laterals shall be owned and controlled by the latter. That water shall be delivered by the company into a lateral or ditch to be provided by the consumer from a box or weir through the banks of the company's canal or lateral to be provided by it. That the consumer will use no more water than his contract authorizes and only at such stated times as shall be designated by the company and distributed to him by its water master, and will not furnish water to any other person on penalty of forfeiting his right to use of water during the remainder of the season.
>
> SEC. 12. * * * That in case of shortage the company may alternate the use of water among its various consumers, or may distribute the available water pro rata to all its consumers in accordance with such rules and regulations as the company may from time to time deem necessary or expedient.

Originally the chief engineer desired to deliver water to each irrigator in continuous flow, because he felt that delivery in rotation—the general practice in Utah—would place too great a burden on the company, but the water users objected to this arrangement and he was compelled to work out a plan of rotation. This plan provides for a continuous flow in the main canal and in all of the principal laterals, whether owned by the company or by the consumers. The consumers' laterals have been laid out so as to cover an acreage sufficient to require a continuous flow of at least 2.1 cubic feet per second, and water is delivered to all consumers at that rate one hour per week for each acre, regardless of the crop. About four irrigation turns are required for the consumers to water their entire holdings, and consequently they get over the land about once each month during the irrigation season, May 15 to October 15. The minimum acreage under a consumer's lateral is 168, equal to the number of hours in a week. In case of a larger acreage the flow is increased accordingly. The farmers usually like to have an irrigating stream of 2 to 4 cubic feet per second, and a schedule of rotation for the consumers' laterals is arranged by the chief engineer at the beginning of each season and adhered to strictly. This schedule gives the exact time each consumer is to receive water each week. Copies of this are given to the ditch riders and notices sent to consumers, and there is no possibility of controversy as to the time water is due. The following is a copy of the forms used.

Form used by the Utah-Idaho Sugar Company to notify consumers of time they are to receive water each week throughout a season.

No. 5972.

UTAH-IDAHO SUGAR COMPANY.

Date......, 190..

Mr.......................... ....

....

Acres...., Sec...., Tp..... R.......

From......M..........................

Until......M..........................

$......   By ....

UTAH-IDAHO SUGAR COMPANY.   No. 5972.

GARLAND, UTAH, ..., 190..

Mr......

DEAR SIR: Without recognizing any contracts except those made by this company and the Bear River Water Company, your schedule of time for irrigating ...... acres in Sec. ...., Tp. .... N., R. .... W., during the irrigation season of A. D. 190., will be from .... M. .... until .... M. ...... flow.

UTAH-IDAHO SUGAR COMPANY,
Per ....

Water rentals are due May 1, and bear interest at 7 per cent until November 1 and 12 per cent thereafter until paid.

Water is used both day and night, the schedule being changed each year, so that a consumer is not required to do most of his irrigating at night two seasons in succession. The rotation begins with the farmer nearest the turn-out from the main lateral. If any farmer does not wish to irrigate when his turn comes, he is allowed to shut the gate leading to his individual distributing ditch. Each farmer is required to take care of his waste, and as he usually does not have waste ditches it is necessary for him to shut off the supply when no longer needed. This method has proven very satisfactory.

The schedule of irrigation prepared by the chief engineer is supplied to the ditch riders on regular forms on loose leaves for insertion in their field books. This form shows the number of the box from which water is taken, the schedule number by which the farmer is located on the books in the office, the area irrigated, the exact location of the land, the number of the contract under which he is entitled to water, the number of hours for which the stream is to run, the exact time he is to begin taking water, and the exact time that he is to cease.

MEASUREMENTS AND EXPENSES.

Measurements of water under this system are made almost entirely with current meters by a hydrographer employed for six months each year at a salary of $80 to $100 per month. He measures the water both in the main and branch canals and reports to the chief engineer. After the flow in the consumer's ditch is measured the turn-out gate is set and locked at a point that will pass the amount of water called for by the schedule. The chief engineer intends to have every stream delivered to a consumer measured at least once each week during the season, but this can not be done by one man. He succeeds, however, in getting enough measurements to enable him to keep the required amount of water flowing in the consumers' laterals with approximate accuracy.

All of the turn-out gates are owned by the company. In the early days of the canal the consumers were allowed to install their own, but the company claims that these parties have caused much trouble by breaking locks and otherwise molesting the canal, as they have a legal right to remove locks put on their private turn-outs by the company. The turn-outs on the branch canals are numbered consecutively from the turn-out in the main canal. The ditch riders keep careful crop reports for their respective districts, showing the acreage in various crops and the yield of each. The management of the canal finds these crop reports to be good evidence of the kind of water service the consumers get, and in case of dispute use them to refute claims of poor service.

All consumers receiving water from this canal are required to purchase perpetual water rights, costing $35, one-fourth down and the balance in three annual installments, with interest at 6 per cent per annum, and 12 per cent if not paid when due. In addition to the water right, annual rentals are charged to consumers at $1 per acre on land devoted to general farming, $2.50 per acre on land planted to orchards exceeding 5 years old, and $4.50 per acre on city or town lots. The company sought to make the charge increase with the ability of the farmers to pay, but this did not prove satisfactory to the farmers, as it is a well-known fact that less water is required to irrigate orchards than alfalfa.

Water rentals are due for the current year on May 1, and bear interest at 7 per cent until November 1 and at 12 per cent thereafter until paid. Those delinquent in the payment of rentals are required to make satisfactory arrangements with the company before they can receive water.

The annual cost of water delivery is not segregated in the annual reports of the chief engineer. The chief engineer receives $3,000 per annum, one-third of which should probably be charged to water delivery. The general foreman receives $90 per month, the hydrographer $80 to $100 per month when employed, assistant foreman $75 per month, and six ditch riders $75 per month each, or a total for salaries of those concerned in maintenance and operation exclusively of about $8,000. Charging one-half of this to water delivery and $1,500 per year for office expenses, which is the estimate of the chief engineer, makes a total chargeable to water delivery of $5,500, or about 16 cents per acre.

THE DAVIS AND WEBER COUNTIES CANAL.

The Davis and Weber Counties Canal, which receives water from Weber River and East Canyon Creek, is perhaps one of the best examples of a fairly efficient water delivery under simple and inexpensive methods worked out by the farmers themselves. This canal irrigates about 12,000 acres planted to alfalfa, grain, sugar beets, tomatoes, and other crops, with an average flow in its main canal of not more than 150 cubic feet per second. The company which controls the canal is made up of 520 water users. All who have rights to the normal flow of the water sources own primary rights, as is the case with practically all canals in Utah, sharing in such normal flow pro rata according to the number of shares of stock owned. In addition to primary rights, secondary rights have been issued to the flood flow, the holders sharing pro rata with the holders of the primary rights in the total flow of the canal during flood season but are not entitled to water when the floods have passed. This canal was known originally as the Central Canal, and when organized by the present company was receiving its water from the Weber River only. The river, however, soon proved inadequate, and additional stock was issued for the purpose of constructing a reservoir in East Canyon Creek. In the middle of July, when there is not sufficient water in the Weber River to supply the rights, the reservoir is drawn upon and the crops under the canal thus matured.

The total length of the main canal is 9 miles and there are only about 10 miles of main laterals, known as south, west, and north branches. The company attends to water delivery from this main canal and these main branches. There are 15 additional laterals, averaging 1.25 to 7 miles and aggregating 60 miles in length, from which the water is distributed by the irrigators without any expense to the company. There is a superintendent or chief watermaster, who is in charge both of maintenance and operation, at a salary of $4 per day when employed, his total salary in 1907 having been $737. Directly under the chief watermaster is a subwatermaster, whose duties are confined to water delivery and who receives the same rate of pay as the chief watermaster. There are two ditch riders, who patrol the channels, keep them clear of weeds and other obstructions, and prevent and repair breaks, but have no other duties connected with the delivery of water.

Each lateral has a watermaster, who is appointed each year. Some of these receive compensation at the rate of 15 or 20 cents per share of stock, some monthly salaries, and others no compensation. These watermasters receive the water from the main canal or one of its main branches and deliver it to the users under their respective laterals in regular rotation. The usual amount delivered is 4.3 cubic feet per second per acre for one-half hour, regardless of the crop, the intervals between irrigations being six to twelve days, depending upon the individual ideas of the various farmers. At the beginning of each season the secretary of the company sends a card to each watermaster for each irrigator on his lateral, showing the amount of water the irrigator is to receive during the season, and these cards form the watermaster's basis for delivery. These cards are reissued each year, owing to changes from one lateral to another, through rental of shares, and other causes.

No water measurements are taken, and gage readings are taken only occasionally at a rating flume near the head of the canal, but no record of them is kept. The superintendent and subwatermasters are expected to be experts in guessing. The lack of measurements results in a great deal of dissatisfaction during periods of scarcity, and, while many of the irrigators realize the value of them, the inherent desire of the majority to incur no expense not actually necessary has prevented the installation of additional devices.

The cost of water delivery under this canal is merely the cost of employing the superintendent and subwatermasters and the office expenses. The total properly chargeable to delivery in 1907 was not over 10 cents per acre.

THE SOUTH JORDAN CANAL.

The South Jordan Canal receives its supply from the Jordan River, and waters 9,000 acres of alfalfa, grain, and sugar beets south of Murray. It is 18 miles long, has 42 laterals averaging 2 miles in length, and maintains a maximum flow of 142 cubic feet per second during the principal part of the irrigation season. The company is made up of farmers using the water carried, 6,000 shares having been issued at the average rate of one share to each 1.5 acres irrigated. Each share entitles the owner to $\frac{1}{6000}$ of the available supply.

Water delivery is attended to by a watermaster, who receives about $400 per year, being $3 per day for the time actually employed. He arranges and executes his plan of delivery, subject to the direction of the board of directors. At the beginning of each season he is furnished a list showing the number of shares owned by each shareholder on each lateral. The number held on the several laterals varies slightly from year to year, owing to sales and rentals. On receipt of this list, the watermaster turns to each lateral the proportion of the entire supply due all of the shareholders under it, and this volume runs as a continuous stream throughout the season, except during exceedingly dry periods. Exceptions are made for laterals on which less than 200 shares are held, in which case two or more such laterals are combined and treated as one. The duty of the watermaster ends with the division of the water to the laterals. The users on each lateral arrange among themselves a schedule of rotation and appoint one of their number, at a compensation, usually of 10 cents per share per year, to see that the schedule is carried through. The largest stream carried by any lateral is represented by 448 shares, which amounts to 6.5 cubic feet per second when the canal is carrying its full 142 cubic feet per second. The smallest stream is represented by 48 shares, or 0.65 cubic foot per second. In the former case each user receives the full flow for thirty-five minutes for each share owned, and in the latter three hours per share. On nearly all the laterals water is delivered on the basis of one hour per share for each run, runs being so timed that each user receives water every nine or ten days throughout the irrigating season from April 15 to September 15. About 356 irrigators are supplied by the canal.

This canal is one of five taking water from the Jordan River under a court decree defining their respective rights. Measurements are made by a court commissioner, twice each week during the irrigation season, in a rating flume at the head of the canal, and a gage rod is read twice each day. The flow to the laterals is measured over Cipolletti weirs installed short distances below the heads of the laterals. These weirs are made of lumber, without metal crests or sides, and all of the conditions necessary for accurate measurements are not maintained. The velocity of approach, however, is not allowed to exceed 0.5 foot per second, and the results are considered satisfactory by the farmers and are approximately correct.

No daily record of delivery of water to irrigators is kept by the watermaster, such a record not being necessary, as the distribution among the users on the various laterals is arranged among themselves without reference to the watermaster. No record is kept of the amount delivered into the laterals, as the flow is kept as nearly constant throughout the season as the flow in the canal will permit, and much of the fluctuation in the canal is borne equally by the various laterals. The flow in the various laterals is affected to some extent by differences in the grade, size of opening of the outlet from the main channel, obstructions in the canal and laterals, and it is necessary for the watermaster to spend much of his time along the canal adjusting headgates, removing obstructions as they accumulate, and making measurements at each weir three times a week. Satisfactory delivery under this system is prevented by the growth of water grass in the canal, which has a tendency to hold the water at a high level in the canal, thus increasing the discharge through some of the headgates.

The total annual cost of water delivery averages about $1,350, or 15 cents per acre, of which about $150 is paid to the secretary, $400 to the watermaster, and about $200 for the services of the court commissioner at the headgate. The remaining $600 is for maintaining the schedules on sublaterals, at 10 cents per share.

THE UTAH AND SALT LAKE CANAL.

This canal takes water from the Jordan River. Like the South Jordan Canal, its supply is apportioned by a commissioner of the district court, the rating flume at the head of the canal being rated by the court commissioner at the same time as that of the South Jordan Canal. The main canal is 26 miles long, with 52 lateral ditches from 1.5 to 2 miles long. The canal irrigates about 13,000 acres, 9,000 in alfalfa and 3,000 in grain. The maximum capactiy is 246 cubic feet per second, and the average flow about 200 cubic feet per second. The ownership in the canal is represented by 10,000 shares of the Utah and Salt Lake Canal Company, controlled by 510 irrigators.

The plan of delivery is similar to that followed on the South Jordan Canal except that instead of using Cipolletti weirs of standard length and altering the depth of flow over them according to the quantity to be run, the watermaster has installed rectangular weirs with lengths proportional to the number of shares represented on the laterals, and the depth of water over the crests of all of these weirs is maintained equal or as nearly so as possible. Each share on a lateral is represented by one-eighth of an inch in length of weir crest. When shares are transferred from one lateral to another the weirs are increased in length by sawing off a portion of one or both sides, or decreased by nailing on cleats. These alterations are made at the beginning of each season, as practically no transfers are made after irrigation begins. This method of altering the size of the weirs is crude but easy and is accepted as satisfactory by most of the water users. The weir boards are made of 1 and 2 inch material and the crests and sides are not beveled to give a thin edge. The proper conditions of the grade and the width and depth beyond and below the crests are not maintained and the velocity of approach therefore varies considerably, so that in reality the measurements are little more than approximations.

The watermaster is provided at the beginning of the season with a list of shareholders, segregated by laterals. There is also some one on each lateral who looks after the division among the farmers on the lateral, receiving pay from his neighbors at the rate of 5 cents per share per year, either in cash or in water.

The size of stream delivered depends upon the number of shares each user owns. The smallest stream is delivered to the owners of 68 shares, being 1.36 cubic feet per second when the average of 200 cubic feet per second is carried in the main canal. Each user receives this stream for one hour per share at each irrigation, the intervals between irrigations being eight or nine days, as arranged by the users on each lateral. The largest stream is that delivered to the owners of

522 shares, and amounts to 10.44 cubic feet per second, and is allowed for twenty minutes per share at each irrigation.

The watermaster receives $3 per day for the time actually employed, amounting to about $500 per year. The secretary receives $300 per year, of which $200 is properly chargeable to distribution. Counting the amount paid to subwatermasters on the laterals, at the rate of 5 cents per share per year, the total expense properly chargeable to delivery is approximately $1,200 per year, or a little over 9 cents per acre.

THE UPPER CANAL IRRIGATION COMPANY.

The Upper Canal is a small canal receiving water from Big Cottonwood Creek near Murray, and supplying a total of 1,500 acres of land farmed by 184 farmers. Alfalfa is the chief crop, but the section covered by the canal is a rather favored orchard belt, about 300 acres being in fruit trees, nursery stock, and grain. The main canal is only 15 miles long, beginning in Big Cottonwood Creek at the point of intake of the conduit supplying Salt Lake City. There are 57 small laterals, aggregating 23 miles in length. On 32 of these laterals water is run during the entire year for stock and domestic purposes. The maximum flow is 60 cubic feet per second and the average only about one-half of that amount.

Water delivery under this system is attended to by one man, who receives a salary of $270 and is employed only during the summer months. Water is delivered on a time basis and is measured over small Cipolletti weirs set in the channels of the canals without boxes or flumes. The irrigation schedule is followed very carefully and irrigators receive water in proportion to the shares of stock owned. The amount delivered for orchards, potatoes, berries, and nursery stock is 2 cubic feet per second; for grain, 3 cubic feet per second; and for alfalfa, 4 cubic feet per second. The water is run two hours for all crops receiving an irrigating head of 2 cubic feet per second, one and one-half hours for grain, which receives a head of 3 cubic feet per second, and one hour for alfalfa, which receives a head of 4 cubic feet per second.

The plan of delivery on this system is very simple, yet it seems to be all that is necessary. Each irrigator knows what his share is and relies on the ditch tender to see that he gets it. No records are kept of the measurements on the laterals, but a record is kept showing the flow in the main canal.

The only expense for water delivery is the salary of the ditch tender, and the cost per acre is only about 18 cents per year.

SYSTEMS USED ON TYPICAL CANALS IN NEW MEXICO AND ARIZONA.

THE NORTHERN CANAL IN NEW MEXICO.

The Northern Canal at Hagerman, owned and operated by the Hagerman Irrigation Company, has its sources of supply in North and South Springs and Berindo rivers and artesian wells. The main canal is 35 miles long and the aggregate length of the principal laterals is 75 miles. Ten thousand acres are irrigated by the canal, 4,000 in alfalfa and 6,000 in orchards, with corn, alfalfa, and potatoes between the rows in about one-third of the orchards. The maximum flow in the main canal is 180 cubic feet per second, and the average flow during the irrigating season from March 1 to November 1, 57 cubic feet per second. One hundred and sixty-five irrigators are supplied by the canal, all of the shareholders being irrigators.

This canal, although one of the smaller of the systems considered in this bulletin, has relatively one of the most complete systems of water delivery. It is under the direct supervision of a water superintendent who has two ditch riders under him. The superintendent directs both the canal maintenance and the water delivery, there being no engineer. He also performs all clerical work connected with the system. Each ditch rider covers 8 miles of main canal and 35 miles of laterals. The superintendent gives them written instructions, indicating the importance attached to accuracy and faithfulness on the part of the ditch riders. These instructions are given in full below:

Written instructions to ditch riders of the Hagerman Irrigation Company.

HAGERMAN, N. MEX.

Mr. ——— ———,

Ditch rider, District No. ——.

DEAR SIR: 1. In your capacity as ditch rider for this company, it will be your duty to take proper care of all gates, weirs, measuring boxes or flumes used for the delivery of water to the consumer, and when same are out of repair and you are unable to make necessary repairs, you will promptly notify this office.

2. I wish you to exercise the greatest care in handling of water. Be sure that you are correct on all measurements, and before you time water through measuring box, flume, or weir, see that it is clear and true.

3. Be prompt in making your settlements with consumer. It will save you time and trouble and will be more satisfactory to all concerned.

4. Turn in your daily records on the first of each month and water cards not later than 10th of each month.

5. You will deliver no water on "water right" land until first having received notice from this office that rents due have been paid on said land.

6. You may require that twenty-four hours' notice be given for the delivery of water, and six hours' notice for shutting off same.

7. Parties buying special water will be required to provide all necessary ditches, gates, weirs, etc., for the delivery of same.

8. Notify all parties receiving "special" or "excess" water that no deliveries will be made for amounts less than $1.

9. You will promptly notify all property holders who have fences, bridges, or other obstructions across the canal or main laterals that they must keep them out of the water, and must not set posts or other obstructions that will catch moss or trash of any kind, and thereby obstruct the free flow of water through said canal and lateral.

10. You will be expected to use every courtesy in your treatment and business transactions with the farmers, be ever ready to consider any claim or grievance they may have to present, be fair yet firm in your decisions, be sure that each one understands the honesty of your purpose and that you are trying to give all the best possible service.

——— ———,
Superintendent.

Under the water rights issued the consumers are entitled to receive 30 acre-inches of water per acre per annum, or 108,900 cubic feet, for which they pay $1.25. Water in excess of this amount is charged for at 5 cents per acre-inch, or 3,630 cubic feet. The consumers notify the ditch rider when water is wanted and the amount desired, and it is delivered as near that time as the supply permits. A regular form for application for water is provided, but this is not used in making applications for water, being filled out by the ditch rider in duplicate and signed by the consumer at the time of delivery. The original is kept by the ditch rider and turned into the office of the superintendent at the end of the month and the duplicate is retained by the consumer.

The usual size of stream delivered to irrigators is 3 cubic feet per second for orchards and 5 to 8 cubic feet per second for alfalfa. Time rotation is not followed on the system. Cipolletti weirs and rated measuring flumes are used for measuring water to the consumers, there being 105 such devices on the system. Weirs are used where the canal grade is sufficient to give a free overfall, and where it is not sufficient measuring flumes are used. The policy of the company is to measure water to each consumer separately and at a point as near to the consumer's headgate as possible, except in cases where consumers are located so that one measuring device will answer for more than one.

Daily records of the amount of water running through each headgate are kept on small slips and turned in to the superintendent at the end of each month and show the total amount of water allowed to each user.

For the monthly report made to the directors a form is used providing spaces for the name of each user, the number of acres irrigated, the total number of cubic feet used up to the end of the month for which the report is given, the excess over the allowance on the water-right contract delivered to each user, the "special" water used during each month, and the amount due on "excess" and "special" water for the month. A ledger account also is kept for each individual consumer, showing when water was delivered and how the account of each consumer stands.

In addition to furnishing a basis for water charges and as a check to delivery the above report gives approximate data regarding the duty of water under the canal. The superintendent reports that after thirteen years of experience with the present system he "can testify that the farmers seem entirely satisfied with the manner of distribution and delivery and are not asking or making suggestions for any change."

The total cost of water delivery under the Northern Canal is placed by the superintendent at $1,490 per year, or about 15 cents per acre. This includes one-third of the superintendent's salary of $100 per month, $1,050 paid to the two ditch riders at $75 per month each, and $40 for office expenses.

THE TEMPE CANAL IN ARIZONA.

The Tempe Irrigating Canal supplies water from Salt River to 185 irrigators at Tempe, Ariz., and is owned and operated by the farmers using the water. The main canal is only 4 miles long, and supplies 34 miles of principal laterals and waters 21,600 acres—14,000 in alfalfa and 7,000 in grain. The maximum flow in the canal is 475 cubic feet per second and the average flow throughout the year 145 cubic feet per second.

Water delivery is under the direct charge of a superintendent who receives $110 a month and who has under him two zanjeros at $85 per month each. He has entire charge of both maintenance and delivery under the general direction of the board of directors. Each zanjero covers about 20 miles of canal and laterals, and often finds it necessary to ride 35 or 40 miles a day. The cost of delivery averages 14 cents per acre per year.

Water is delivered in rotation, the length of time each user receives it depending upon the number of shares owned, which is not uniform, as some land requires more water than other land and the irrigators have bartered the stock among themselves until each holds the number of shares necessary to supply the water required. It is customary to keep a steady flow in each of the main laterals and to rotate on these laterals, starting at the upper end of each. The amount to be delivered to each user depends on the supply available, being usually 400 to 1,000 miner's inches, or 10 to 25 cubic feet per second. The superintendent notifies the zanjeros of the size of stream in the main laterals, who distribute such flow in accordance with their general instructions and the amount due each irrigator.

The way in which this is done is shown by the following description furnished by C. G. Jones, president of the company:

> We distribute water according to the number of shares owned in the canal and usually run it for twenty-four hours to 1 share, twelve hours to ½ share, six hours to ¼ share, etc., the stream or irrigating head run to each irrigator varying from 400 to 600 inches.
>
> We will suppose that the superintendent notifies the zanjero that at 12 o'clock noon, June 1, 1,800 inches, or 45 cubic feet per second, will be turned into the head of a principal lateral, to be divided into 3 irrigating heads. The zanjero then notifies the first irrigator on sublateral No. 1 that his head of water will be turned to him at 12 o'clock noon on June 1, presuming that sublateral No. 1 takes out close to the head of the principal lateral. This user is told that he will receive water forty-eight hours. The zanjero then goes to sublateral No. 2 and notifies the first user (A) that the second head will be turned into sublateral No. 2 at 12.30 p. m., June 1, which allows thirty minutes for water to run from the head of the principal lateral to the head of sublateral No. 2; the zanjero also notifies the second user (B) on sublateral No. 2 when water will be turned in sublateral No. 2, that A will use it for the first six hours and will then turn it down at 6.30 p. m. the same day to B. The zanjero also tells B to see that A turns it down on time, and should A refuse to turn it down on time no water will be given him at the next run, and he may be prosecuted under the law. Prosecution under the law, however, is unnecessary. B receives the water at 6.45 p. m., allowing fifteen minutes for it to run from A's check, and uses it for nine hours, when he turns it down to C. In the meantime the zanjero has notified C and D and E as he has A and B when the water is turned into sublateral No. 2 at what time each should receive it and turn it on to the next user. When the number of hours on sublateral No. 2 has been run the zanjero closes the headgate at the principal lateral. A has now had water for six hours, B for nine hours, etc., in all fifty-four hours. In the meantime the third head of water has also been turned from the principal lateral, first going into sublateral No. 3 at 1 p. m. on June 1, the day the first two heads were turned out above. As the users on sublateral No. 3 have the least number of hours to run the third head will first be ready to be returned to the main lateral. The time for this is 12.30 o'clock midnight, June 3, the water on this head going to sublateral No. 4 for twelve hours. Now at noon, June 3, the head in sublateral No. 1 is out and it will be turned to sublateral No. 5 for eighty-four hours. Thus as the runs in the sublaterals above are completed the heads are taken down to the sublaterals below until all are served with their proper number of hours, when rotation is begun over again, starting as before with sublateral No. 1. When the river is normal, or above normal, irrigators will receive irrigating heads every six to ten days. As this is a suitable length of time between irrigations for practically all crops, we make no special difference between users on account of crop grown. Irrigators can receive no water except in regular turn and after having been verbally notified by the zanjero of the time water is to be delivered.
>
> Our plan of delivery has been in practice for a number of years and has been perfected from time to time as occasion has required. It is now considered the best system in the Southwest for distributing water from a river with an irregular flow where the farming is stock raising and the growth of hay and grain.

The superintendent keeps a record of all water delivered to the canal system, made up from reports received twice a day from the gage reader on the river. He also keeps an accurate account of the amount turned into each principal lateral, this amount being in proportion to the number of shares owned on such lateral and divided into irrigating heads as he may direct. These heads are measured and checked by means of sections that have been rated with a current meter, sometimes as often as twice a month, each rating section being provided with the customary gage rods. The measurements reported to the superintendent are kept in a book for that purpose. The zanjeros also keep account of the amount of water and the number of hours run to each irrigator.

The following brief rules and regulations are the only written guide for the zanjeros relating to the delivery of water.

Rules governing water delivery.

1. That no small stream or head of water, except in regular turns, shall be run for watering of stock.
2. That no one except such as are duly authorized by the board of directors shall handle any gates or checks in the canal or branches.
3. That when assessments are delinquent no water shall be run to such shares of stock until all delinquencies are paid.
4. That the zanjeros shall notify each water user when he shall receive the water not less than twenty-four hours beforehand and shall handle the gates and checks in the canal of which he has charge, under the direction of the superintendent.

THE SALT RIVER VALLEY CANALS.

Mr. C. G. Jones, president of the Tempe Irrigating Canal Company, supplies the following description of the methods of water delivery under the canals on the north side of Salt River. These canals are now controlled by the United States Reclamation Service:

The maximum capacity of these four canals when in good condition is 1,000 cubic feet per second and they irrigate 78,500 acres.

The first step necessary after the Government took control was to put the canals in shape and then to adopt some plan of distribution. The first thing was a consolidation of all parallel laterals into one lateral capable of carrying one or more irrigating heads of from 400 to 700 inches, or 10 to 14 cubic feet per second, and to supply these laterals with proper headgates, checks, and measuring devices. Where practicable the Government installed concrete headgates and weirs.

The plan of delivery determined on was to deliver water to irrigators in rotation with a uniform head given to the user for the number of minutes proportional to the number of acres watered. A plan of rotation was so arranged that irrigators should receive water at intervals of from four to eight days and the rotations were begun at the head of each lateral.

A sufficient number of zanjeros has been employed to enable the system to be covered by rides of not to exceed 20 to 30 miles per day for each zanjero. Each zanjero has to notify each irrigator when he can receive water and how long he is to keep it for each acre. The zanjero performs the duties connected with his work, keeping the superintendent familiar with the conditions of the laterals and canals within his beat.

One of the engineers of the Reclamation Service has control of water delivery. This officer indicates to the zanjeros what size of head to run and for what length of time each irrigator is to receive such head, of course determining this by the supply available. He sees that all measuring devices are accurate, that all laterals are in proper shape to receive water without waste.

Although the Government still retains the practice of the old company of charging for water at a stipulated rate, the system of charging each acre a proportional amount for the actual cost of maintenance and operation will be adopted as soon as the system is in shape.

Uniformity of irrigating heads is merely a matter of the practical handling of water. One irrigator may be able to get along with 100 inches, another with 200 inches, while another may want 500 inches. This can be easily arranged, the difference being made up in the length of time each user receives water.

Under a system of any size it is practically impossible to keep any accurate account of the water without an immense amount of bookkeeping, and this is poor satisfaction to the irrigator.

While for some crops it is hard to use a large head of irrigating water, by a systematic arrangement of the land to be irrigated the disadvantage of a large head can be largely overcome. For instance, a man who has 10 acres in garden and 10 acres in alfalfa can easily divide his irrigating head after it is turned to him, using a small head on his garden and the larger head on his alfalfa. This does not interfere with the canal system or inconvenience his neighbor, and still enables the irrigator to economize in irrigating.

SYSTEMS USED ON CANALS FROM THE HOOD RIVER IN OREGON.

The rich strawberry and orchard lands of Hood River Valley, Oregon, are supplied by two small canals—the Farmers' Irrigating Canal and the East Fork Irrigating Canal—whose delivery systems are worth considering. About 1,500 acres are watered by each.

FARMERS' IRRIGATING CANAL.

This canal has a length of 13 miles and the average flow is about 3,000 miner's inches. Water delivery is in charge of the manager of the company, who receives $4 per day for the time actually employed, amounting to about $150 per year. The direct work of distribution is attended to by three ditch walkers, each of whom receives $65 or $70 per month for five months each year. It is unlawful for any water user to tamper with the laterals in any manner, and the 236 irrigators are required to apply to one of these ditch walkers for any change desired. Few changes are made, the water running continuously as first measured out to users in the spring, except for fluctuations in the flow of the supply from the river. The amount of water usually contracted for by the irrigators is 1 miner's inch per acre, but as the measuring boxes are only approximately accurate the actual amount delivered varies considerably. A large acreage of strawberries is irrigated under this canal, the strawberries being planted between the trees during the first few years of growth and irrigated each day during the picking season, which lasts usually from May 20 to June 20. The orchards are irrigated at varying intervals, depending upon the views of the individual irrigators. The size of the irrigating head varies with the number of shares held, seldom being less than 5 miner's inches or more than 25 miner's inches. No records of any kind are kept and no office expenses incurred in connection with delivery. The total annual cost of delivery, including the entire salary of the manager and three ditch walkers, is about $1,600.

THE EAST FORK IRRIGATING CANAL.

This canal receives its supply from the East Fork of Hood River. The main canal is 11 miles long, with three main laterals having an aggregate length of 26 miles. In 1908 the company distributed 850 miner's inches at the rate of 1 inch for every 2 acres irrigated. Less water is required under this canal than under the Farmers' Canal, as the land irrigated is devoted almost exclusively to orchards. No accurate measurement is taken of the flow in the main canals or in the laterals, but it sometimes reaches over 1,600 inches, which is the number represented by the shares of stock sold. The by-laws place no limit on the amount of water an irrigator may purchase, but the annual expenses are proportionate to the number of shares held. Each stockholder is expected to make application to the secretary on March 1 of each year, stating the amount of water he expects to use for the ensuing season, and he is charged with that amount upon the books of the company. If he fails to make application he is taxed for the amount represented by the number of shares he holds in the company. The general manager of the company has charge of distribution and receives a salary of $1,000 per year. He devotes his time to the work of maintenance and operation and has under his direct supervision three ditch riders at $50 per month each for five months of each year. Their duties are similar to the duties of the ditch riders employed on the Farmers' Canal, being required to make all changes in the measuring boxes. Each irrigator is entitled to a continuous flow of water, depending upon the number of shares he holds, and in nearly every case a continuous flow is called for.

Under both the Farmers' and the East Fork canals water is measured with miner's-inch boxes with a spillback into the canal to maintain the required pressure. All openings in these boxes are 2 inches in depth and the pressure maintained is 6 inches from the center of these openings (fig. 7). Accurate measurement is not expected, but the approximate results give entire satisfaction, as the inaccuracies are about equal in all of the boxes.

SYSTEMS USED ON UNITED STATES RECLAMATION SERVICE PROJECTS.

With construction completed and settlement under way on a number of its irrigation projects, the United States Reclamation Service now has before it the many difficult questions of canal management. The task of working out these questions has been assigned to some of the ablest engineers and managers in the Service. Through the courtesy of those directly in charge, data on what has thus far been accomplished on its project at Sunnyside, Wash., and the Truckee-Carson project in Nevada, are made a part of this bulletin.

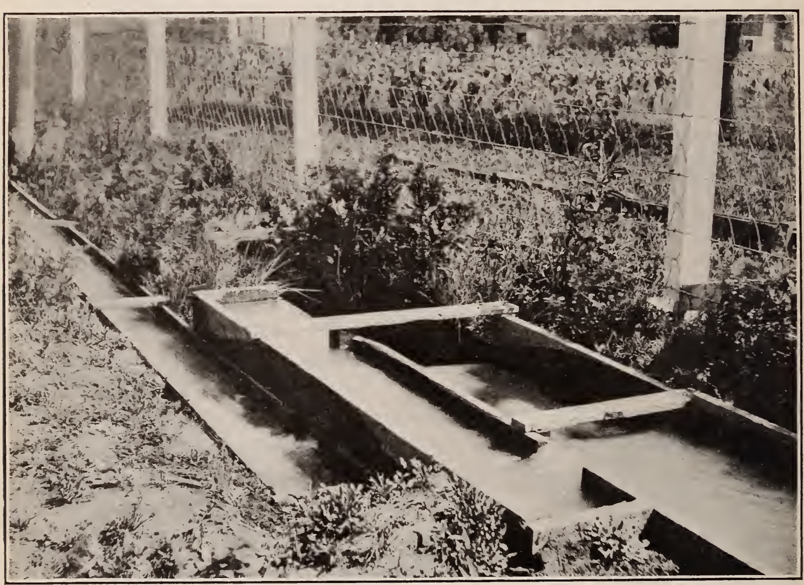

Fig. 7.—" Foote " miner's-inch box used on Hood River Canal.

THE SUNNYSIDE PROJECT.

The Sunnyside Canal, formerly owned by the Washington Irrigation Company and later purchased by the United States Reclamation Service, is now operated as a part of its Yakima-Sunnyside project, and from the standpoint of management probably is the most interesting system operated by the Reclamation Service. Its importance has prompted the management to use great care and thoroughness in planning its water delivery, on its own account as well as an example to other projects, and more money has been expended probably on this feature of management than would have been justified on a system wholly independent of others. The manager under the former ownership has been retained as manager by the Reclamation Service. Prior to the purchase of the canal by the Government this official had worked out one of the most complete systems of delivery to be found in this country. With his former experience and the means afforded by the funds of the Reclamation Service, he is now in position to accomplish much in the matter of water delivery, both for the Government and for private systems.

The Sunnyside Canal is the largest in Washington. The area irrigated in 1908 was 42,000 acres—9,000 acres in orchards, about 27,000 in timothy, clover, and alfalfa, and the remainder mostly in potatoes. The total length of the main canal is 59.47 miles and the aggregate length of the 225 laterals about 500 miles, the largest being Snipes Mountain lateral, which is 13.5 miles long, carries 90 cubic feet of water per second, and irrigates 6,000 acres. The maximum flow in the main canal is 600 cubic feet per second and the average during the irrigation season 575 cubic feet per second. The manager of the system has charge of canal maintenance and operation as well as of everything connected with the settlement of the project. A competent engineer is employed for the purely engineering work of operation, and an experienced water superintendent has charge of the ordinary canal maintenance and of the direction of the flow in the canal and delivery to the users. There are 12 patrolmen working under the superintendent, patrolling the canal and making deliveries to the users. The superintendent is the only official other than the manager who can authorize a change in the headgates. He spends nearly his entire time in the field supervising the patrolmen, receiving and investigating all complaints, and making written reports to the manager. He also inspects the reports of the patrolmen as sent to the office, makes weekly-service reports to the manager, and special investigations and written reports thereon, as requested from time to time by the manager. Besides these officials, the project has the services of a resident hydrographer, who devotes his entire time to making current-meter ratings at the various rating stations of the system, adjusting lateral weirs, and performing other duties connected with the measurement of water on the system. He and his assistant spend a large part of their time in the field in connection with this work.

The topography of the land within an irrigation project, the character of the soil, and the crops to be irrigated dictate largely the plan of water delivery to be followed. The conditions on the Sunnyside

Canal in the early days led to the supplying of a continuous flow of water to each irrigator, and this has come to be the established system. Almost the entire territory covered by this canal is rolling, and the system of laterals necessary to cover such lands is hardly comparable with the checkerboard system used where the land is comparatively flat. It is necessary for the laterals to be taken from the main canal along the highest ridges in order to water both sides of these ridges, as depressions of 50 feet or more lie between the ridges in some cases. It is practically out of the question to use a head of as much as a single cubic foot per second on such light and rolling land as that under the Sunnyside project, while on level land a stream of 1, 2, or even 3 cubic feet per second is almost essential for economical irrigation. Consequently the use of furrows as distributaries has come to be general under the system. While water is now delivered in a continuous flow from the entire Sunnyside Canal, it is not at all unlikely that time rotation will be adopted under a portion of the system. If it is adopted, it will be because careful experiment has proved it suitable and economical.

PLAN OF DELIVERY.

In organizing the Sunnyside project for water delivery the manager established 12 divisions or beats, for each of which a patrolman is provided. These patrolmen answer by telephone the first call from the manager's office at Zillah at 6 o'clock every morning and report the amount of water entering their respective beats. They are supposed to be out on their beats at 7 o'clock, and between 9 and 10.30 a. m. they are required to give a second report to the office, stating the sizes of all the streams being diverted from the main canal within their respective beats. This report shows the office at Zillah that the patrolmen have covered the main canal. During the remainder of the day their duties are on the laterals. They are expected to follow a regular routine and be at any point on the system at the same time each day. They travel on horseback and carry shovels, empty sacks for use in stopping breaks, poisoned wheat for killing sage rats, and poisoned raisins for killing gophers. The manager believes the patrolmen are in better position to see the condition of the canal and laterals if riding on horseback than if riding in a cart or buggy.

During the season of 1908 the patrolmen read 237 weirs daily, exclusive of the 2,500 or more weirs or miner's-inch boxes at the heads of the farmers' laterals. The manager believes that eventually it may be possible to organize the system so that the duties of the patrolmen will end with measuring the water into the laterals and to organize the irrigators under the various laterals into associations to divide the water among themselves. Such an organization would coincide with the manager's idea that eventually a continuous flow may be maintained in each lateral and rotation practiced among the users. In 1908 he made deliveries on five laterals with a view to working out a scheme by which the deliveries could be made by the farmers themselves, and also kept complete records of seepage measurement taken twice daily on these laterals to learn the loss that would have to be accounted for after the water was diverted from the main canal.

Close adherence to all of the rules and strict compliance with routine duties are made features of water delivery by the manager. At the beginning of each season and at intervals during it he gives written instructions and comments upon the conduct of the system to the patrolmen, who are provided with ample means for carrying them out and held to the letter of their instructions. Each is given a diary, substantially bound, with a full page for each day of the irrigation season, in which he is expected to keep a complete account of his work for each day. On the inside of the front cover provision is made for slipping a blank for entering the flow in the main canal and at each main lateral for every day of the week, new forms being provided each week and the completed forms filed in the office of the manager. Each patrolman is also provided with two weir tables, one being for use on land which holds what is called the Washington irrigation water right, issued by Washington Irrigation Company prior to the purchase of the system by the Reclamation Service, each right being for not to exceed 1 cubic foot per second for each 160 acres irrigated; the other provides for water rights issued by the Reclamation Service, which are not to exceed 3 acre-feet per acre per year. These tables show the number of cubic feet per second to be delivered for the various sized holdings from 3 to 640 acres, and the depth over weir crests necessary to get such a flow. This depth has been expressed in feet and inches, but it is the intention of the manager to substitute feet and tenths. The depth on weir crests is shown for the three sizes of weirs used in making individual deliveries, namely, 6 inches, 1 foot, and 2 feet. The following are copies of the weir tables used:

Weir table used by patrolmen on the Sunnyside project for Washington Irrigation Company water rights.

[Allowance 1 cubic foot per second to each 160 acres.]

Acres.	Contract quantity.			
	Cubic feet per second.	Depth on weir.		
		6-inch weir.	1-foot weir.	2-foot weir.
		Inches.	*Inches.*	*Inches.*
3	0.018	⅝	⅜	¼
4	.025	¾	½	⅜
5	.031	⅞	⅝	⅜
7	.043	1	¾	½
10	.062	1⅜	⅞	⅝
12	.075	1⅝	1	⅝
15	.094	1¾	1¼	¾
18	.112	2	1⅜	⅞
20	.125	2⅛	1½	⅞
25	.156	....	1⅝	1
30	.187	....	1¾	1¼
35	.219	....	1⅞	1⅜
40	.250	....	2⅛	1⅜
45	.281	....	2⅜	1½
50	.312	....	2½	1½
60	.375	....	2⅞	1¾
80	.500	....	3½	2⅛
100	.625	....	4	2½
120	.750	....	4½	2¾
160	1.000	....	5⅜	3½
200	1.250	....	6¼	4
240	1.500	....	7⅛	4½
320	2.000	....	8½	5½
400	2.500	....	10	6¼
480	3.000	....	11⅛	7⅛
640	4.000	....	13⅜	8½

Weir table used by patrolmen on the Sunnyside project for Reclamation Service water rights.

[Allowance, 3 acre-feet per acre.]

Acres.	Quantity.			
	Cubic feet per second.	Depth on weir.		
		6-inch weir.	1-foot weir.	2-foot weir.
		Inches.	*Inches.*	*Inches.*
3	0.022	⅝	⅜	¼
4	.029	¾	½	¼
5	.036	⅞	⅝	⅜
7	.050	1¼	¾	½
10	.072	1½	⅞	⅝
12	.086	1¾	1	⅝
15	.108	2	1¼	¾
18	.130	2⅛	1⅜	¾
20	.144	2¼	1½	⅞
25	.180	....	1¾	1⅛
30	.216	....	1⅞	1¼
35	.252	....	2⅛	1⅜
40	.289	....	2⅜	1½
45	.325	....	2½	1⅝
50	.361	....	2¾	1¾
60	.433	....	3	1⅞
80	.570	....	3¾	2⅜
100	.722	....	4¼	2¾
120	.866	....	4⅞	3
160	1.153	....	5⅞	3¾
200	1.443	....	6⅞	4¼
240	1.731	....	7¾	4⅞
320	2.309	....	9⅜	5⅞
400	2.886	....	10⅞	6⅞
480	3.464	....	12¼	7¾
640	4.618	....	14⅞	9⅜

Patrolmen are also provided with plats of their respective beats showing the location of the canal and laterals, and each is given a book showing the name of each user on his beat, with a description of his holding, taken from the contract on file in the office of the project at Zillah, the acreage irrigated, and the number of deliveries to be made on each. Thus the patrolmen may know what each irrigator in their respective beats is entitled to receive, and it is their duty to see that he receives it.

The devices for water measurement on the Sunnyside system are as complete as the other means for delivery. Measurements are made on the main canal at its head and at the upper end of each beat by means of rated sections of the canal. These sections have been selected where the channel provides the most satisfactory conditions for measurements, and are rated at short intervals by the resident hydrographer. There is also a rating station in each wasteway and at the heads of the three largest laterals. Gage rods have been installed at all of the rating stations.

In the upper beat known as No. 1 and part of No. 2, comprising about 3,200 acres, water is measured through miner's-inch boxes in accordance with the early water-right contracts made a number of years prior to the acquirement of the canal by the Reclamation Service. These boxes have openings 2 inches high with spillways opposite the openings high enough to maintain a 6-inch head over the tops of the openings. Throughout the rest of the system carefully constructed Cipolletti weirs are installed at the heads of the laterals and also at each point of delivery to irrigators. While the Reclamation Service constructs and maintains only the laterals having a capacity of 20 cubic feet per second or more, it places and maintains all the weirs. The 1-foot weirs are built at a total cost of about $12 each, and the others in proportion. Each lateral is numbered according to its distance from the head of the canal, the number of the lateral indicating the distance in miles.

The weirs on the laterals are numbered consecutively, beginning with 1 at the head of each lateral. Figure 8 shows the Cipolletti weir at the head of one of the laterals near Zillah and figure 9 weir No. 2 on the same lateral, with the division box and regulating gate connected with it. The weirs are located carefully in order to get the essential conditions for accurate measurement, the crests and sides being covered with zinc so as to give the sharp edge required for accuracy. The headgates on the laterals and gates at the farmers' weirs are kept locked, and no one has a key except the officers connected with water delivery and measurement. The crests of the weirs at the heads of the laterals vary in length from 1 foot to 9 feet and the crests in the individual weirs have lengths of 6 inches to 2 feet.

RECORDS.

No other system visited in connection with the investigation on which this bulletin is based was provided with such complete forms for keeping records as the Sunnyside Canal. Each patrolman is provided with a diary for noting work done, plat of his beat, list of irrigators in his beat, with area and location of each holding, weir tables, and form for weekly report of water run. As the weir tables show the amount of water due each sized holding, the patrolmen have merely to maintain such an amount flowing over the weirs, a comparatively simple matter after the gates are set and locked.

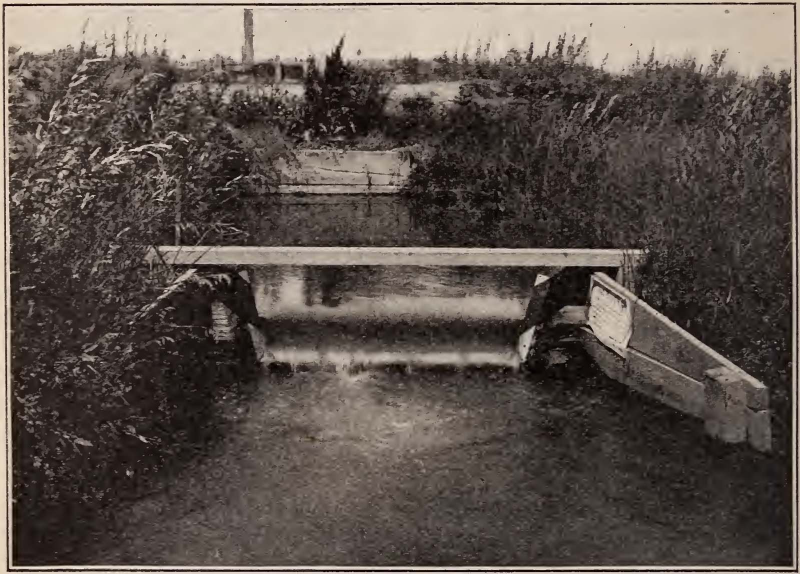

Fig. 8.—Cipolletti weir at head of lateral on Sunnyside project.

These daily records do not include the amount run to each irrigator, but rather the amount run through each headgate or "heading" lateral leading from the main canal. After the patrolmen have entered on their weekly report cards the amount of water passing each gaging station and into each lateral in their respective beats, the records are telephoned to the office at Zillah and entered on a large sheet by the recording clerk. There is a sheet for each day, on which space is provided for an entry of the flow at the upper and lower ends of each beat and the time of day of the gagings by the patrolmen, also similar data from each lateral leading from the main canal, there being columns to show the number and size of each weir and the normal depth over its crest. The amounts carried by the various laterals are totaled and entry made of the amount of water actually used, the amount wasted, and the seepage and evaporation losses. The difference between the water entering each beat and the water delivered over laterals or wasted at the lower ends of the laterals is entered under the head of seepage and evaporation losses, thus absorbing any errors of measurement. Under the Truckee-Carson project in Nevada, these losses are classed by the more accurate term of "invisible losses." From the daily report sheets the recording clerk makes up daily, weekly, and monthly summaries, all substantially in the same form, and these furnish a complete record of water delivery for the monthly report of the manager to the Director of the Reclamation Service at Washington. The manager of the project also receives weekly reports from the head of each department working under him. The form for the daily summary is given on page 76.

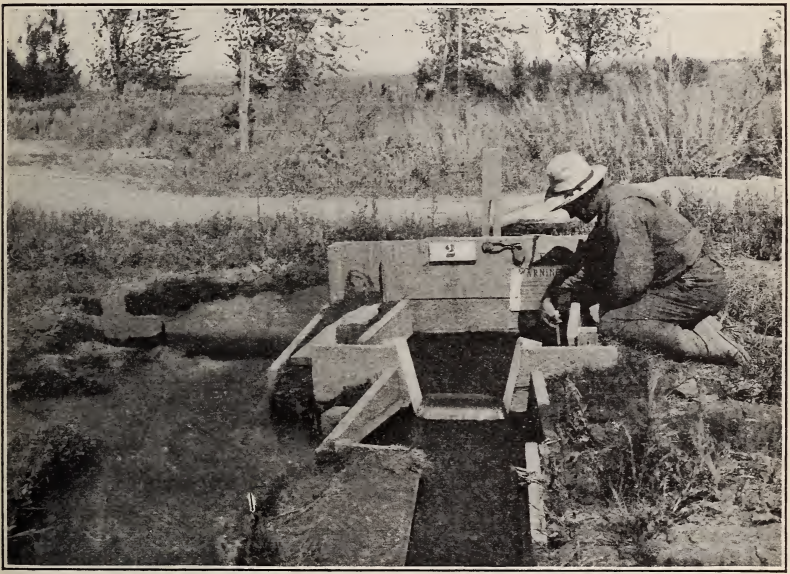

FIG. 9.—Weir diversion box and regulating gate on the Sunnyside project.

Form used by the Reclamation Service for daily water summary on the Sunnyside project.

Department of the Interior,
United States Reclamation Service,
Sunnyside Operating Department.

DAILY WATER SUMMARY.

Beat No.	Name of patrolman.	Station mile No.	Gage height.	Time.	C. F. S.	Water used.	Water turned over weirs.	Zillah wasteway.	Sunnyside wasteway.	Prosser wasteway.	Loss, seepage, and evaporation.	Total acre-feet.	Acres watered.	Acre-feet per acre.	Remarks.
1		0 8													
2		8 17													
3		17 25													
4		25 30													
5		30 38													
6		38 42													
7		42 48													
8		48 52													
9		52 56													
10		0 3													
11		3 9													
12		0 3													
	Total.														

THE TRUCKEE-CARSON PROJECT.

The Truckee-Carson project, the first of the reclamation projects to be opened to settlement, is located in the Carson Sink Valley in western Nevada, and as at present completed covers 100,000 acres of agricultural land thrown open to settlement in 1906. Water was delivered to 225 irrigators in the spring of 1908, and in June following 322 had applied for water, of which 100 were owners of private lands which share the privileges of the project under an agreement with the Reclamation Service. The remaining applicants were homesteaders on the government land of the project, the area homesteaded by them being about 25,000 acres. The principal crop is alfalfa, although the largest area actually watered up to the present time has been pasture.

The plan of water delivery on any project must be developed through experience, and the system now in force in this valley may be changed when more of the land is irrigated. The present system has been worked out with a good deal of care and detail, and offers many valuable suggestions, even though it may be abandoned later for some other system.

When the Truckee-Carson project was thrown open to settlement the canals and laterals had been built to cover practically the entire 100,000 acres. These canals and laterals have an approximate length of 500 miles, of which 85 miles is main canals, 290 miles principal laterals, and 125 miles drain channels. The engineer in charge at the outset was confronted with a stupendous task, for the delivery of water through so many miles of canal to settlers scattered over 100,000 acres was almost impossible. This task was lessened somewhat by restricting the areas open to settlement to a relatively compact area in the general vicinity of the new town of Fallon, which is the center of the project. The maximum amount of water taken into the main canal at the Carson Dam has thus far been 625 cubic feet per second. By August 15 this falls to 400 cubic feet per second, and by November 1 the water is turned out of the canal. Each irrigator under his contract with the Reclamation Service is entitled to 3 acre-feet of water per acre per year. The plan so far, however, has been to allow each irrigator to have water practically on demand for twenty-four hours or some multiple of that time, but it is expected that eventually the stipulation of 3 acre-feet per acre will be strictly adhered to. In fact, the project engineer desires to make such limit at the earliest possible moment, even if there is more water available than will be required for supplying that amount, his idea being that it is highly desirable to restrict the use of water to the actual needs. When the canals and laterals on the project were constructed it was planned that the canal and its branches should contain water continuously throughout the season; that the primary and secondary laterals should carry water for twenty days each month; and that the tertiary laterals should carry water for ten days each month. Whether this plan will be adopted eventually must be determined by experience.

PLAN OF DELIVERY.

The project engineer has organized rather extensive plans for water delivery, and gives his personal attention to the details of delivery as far as possible in connection with his other duties. Under him is a watermaster, who has an office at headquarters and telephone connection with all points on the project. One assistant works in the office or in the field as required. Under the watermaster are 15 ditch tenders and 2 gate tenders, all of whom usually start at a salary of $75 per month, and if satisfactory are raised to $85 per month in the course of three or four months. This entire force is kept under strict discipline and regular hours. Instructions have been printed and each employee is required to comply with them in every particular. The project engineer felt very reticent at first about issuing any printed instructions, knowing that on such a large project it would be necessary to change details constantly so as to comply with emergencies, but he found it desirable to issue such instructions during 1908, although he expects to revise them from time to time to suit conditions. These instructions are printed and bound and are intended to be carried by the operation employees. Such of these instructions as are specially pertinent to this bulletin are printed below.

Instructions for operation employees.

OPERATION.

(1) *Length of irrigating season.*—The irrigating season of the Truckee-Carson project extends from April 1 to October 31. Water will not be delivered at any other season of the year except on instructions from the watermaster.

(3) *Distribution.*—Accommodation should be ever in the minds of the tenders, but the regulations and welfare of the service should be first in all things.

(*a*) Water is not to be delivered for other than irrigating purposes except by special permission from the project engineer.

(*b*) The distribution of water is the most important of the duties of the ditch tenders, and the accuracy and satisfaction with which this work is done is dependent to a great extent on the regularity of the water flow in the canals at the dams. Gate tenders must keep the water flow in the canals uniform. The alarms should be tested every morning and evening to see that they work perfectly, and if in such condition as to require repairs, notify the watermaster at once. Take water from the main canals into the primary laterals through submerged opening. This will keep the amount of water in the lateral more uniform than by taking it over weirs. Keep this opening free from weeds, etc.

(*c*) Water users must give twenty-four hours' notice when water is required. They should state the amount of water and the length of run desired. Ditch tenders will deliver water as soon as possible after notice. Unless twenty-four hours' notice is given, water will be turned off at the time stated in the original request for water.

(*d*) Ditch tenders only shall operate any gate or turn-out on the project. All gates will be locked as soon as possible to prevent any unauthorized person from raising or lowering them.

(*e*) Water entering any farm must be cared for by the owner throughout the period of the run. The head must not be lowered at night. Farmers must care for water both day and night.

(*f*) Drainage ditches must not be used as waste ditches except in cases of emergency. Waste water must be cared for on the farm, and if waste water in any quantity runs off of it, the amount of water turned into the farm should be lessened accordingly by the ditch tender. Any damage made by waste water entering drains must be repaired immediately by the persons responsible for the damage. Ditch tenders should notify the office of such damage. Failure to repair damage of this sort will result in water being refused for the farm until such damage is repaired.

(*g*) The high-water line will be painted on all the structures on the project, and until this is done refer to the watermaster or project engineer for information as to the high-water line on the different ditches. Never under any conditions is the water to be raised above the high-water line.

(*h*) Regulate velocity to prevent cutting of banks. The velocity may be reduced by checking up the water from the structure below. Keep the water always at the height desired when delivering water for irrigating. Gophers are not apt to work below the water line in a ditch bank.

4. *Reports.*—Keep an exact record of water handled and forward it to the Fallon office each day. Use "water report" cards to show the exact amount of water flowing.

(*a*) Telephone reports must be made by ditch and gate tenders at such times as designated by the watermaster. At least one report must be made daily. Gage readings should be taken so as to be ready in time for these telephone reports. If the ditch tender expects to be absent at report time, previous arrangement should be made with the watermaster. In case of failure to make a daily report the ditch or gate tender will be docked one day's time, unless reasonable excuse for such failure can be made.

(*b*) Ditch and gate tenders will report in writing on the 25th of each month to the project engineer. They should report:

I. Breaks in ditches or other trouble necessitating delays in delivery of water.
  (*a*) Cause of trouble.
  (*b*) Time water was turned off.
  (*c*) Time water was turned on after repairs.
  (*d*) Damage to adjoining land caused by break.
  (*e*) Possible damage to lands by delay in delivering water.
  (*f*) Amount of work to repair break.
II. Extermination of rodents.
III. Miscellaneous topics of interest.

(*c*) Time cards must be filled out by each man, showing character of work done every day. These cards are to be sent in at the end of each month.

(*d*) The agricultural census will be taken once a year, probably at the end of the irrigating season. Instructions will be sent with the blanks at that time. Keep familiar with the progress and success in farming on each farm during the summer. This will make the work at census-taking time much lighter.

(*e*) At census-taking time and again about the 1st of May there will be a homestead inspection. Constant observation in your daily trips will help greatly in this work.

5. *General work.*—Establish a regular route over your district and endeavor to visit each take-out at the same time every day. Occasionally reverse your trip, so as to find out if the gates and take-outs are as you left them. In this way you will be more apt to catch the water thief.

(*a*) In case of a break on any of the government ditches, report immediately to the central office by telephone and also by written report.

(*b*) When riding along a telephone line belonging to the service watch for trouble. Broken guy-wires or braces should be reported, and if breaks are found in the lines, make repairs immediately.

(*c*) Keep tumble weeds and other loose material out of the ditches and drains. When allowed to remain dêbris accumulates, the current is diverted, and washing and filling of ditch result. Keep flashboards piled up in an orderly manner, and see that each structure is supplied with them. Allow no rubbish to accumulate about your house or around the structures. The neat and orderly manner in which a ditch rider conducts his work becomes a qualification as to his fitness for the position he holds. Carelessness and negligence will not be tolerated.

(*d*) Inspect all structures, bridges, drops, and take-outs, both timber and concrete, at least once a day or as often as passed. Report immediately all repairs needed.

(*e*) All rising weirs and gate-stands should be well oiled and in condition to work easily.

(*f*) Bridges have been provided at convenient places, and canals or drains must not be crossed at other places. Small ditches and drains may be crossed by fording by arrangement with the project engineer. No permission to establish a ford will be given except where physical conditions are such that a ford can be maintained without danger to property of the United States.

(*g*) No bridges, culverts, boxes, fences, or other structures may be built across any canal, lateral, or drain without written permission of the project engineer, and ditch tenders finding such work going on will require that the written permission be shown or the work stopped.

(*h*) Children must be kept out of our ditches and canals unless in company with a responsible adult. Bathing in the large canals is dangerous and all parties should be so warned. Cattle must not be allowed to water in ditches or drains.

The watermaster calls up all ditch tenders at 6.30 o'clock every morning and receives from them the gage readings at the heads of their various beats and delivers to them such orders as he may have regarding the water to be run. When the water becomes scarce it is expected that each ditch tender will be instructed by the watermaster how much water he is to run in each ditch, but at present this is unnecessary. The watermaster calls all the ditch tenders up again at night, if necessary. He remains in his office practically all of the time to receive reports and give instructions to the ditch tenders. It is planned eventually to provide an inspector who will be on the canal and laterals all of the time and will report to the project engineer not only regarding water delivery and canal operation but also regarding maintenance, for which an entirely separate force is maintained. Each ditch tender at present covers an average of 30 miles each day, and he is supposed to go over his entire beat every day if possible, or at least every other day.

MEASUREMENTS.

The project engineer has no doubt whatever regarding the value of water measurements and he takes many of them and keeps a complete record. The measurements taken are as follows:

1. Gage readings twice a day at the dam at Truckee Lake, at the head of the Truckee canal, and at the Carson dam. These gage readings are telephoned to the watermaster immediately after being taken and are also sent in in writing at the end of each week on cards provided by the Service. The dam at each of these points is made up of a series of gates and the record taken by the gate tender and sent to the office shows the number of these gates that are open at each time of measurement, the distance each gate is opened, and the head of water above each gate; the discharge in cubic feet per second is then added at the office from rating tables based on current meter observations.
2. Measurements in the main canal directly above the head of each primary lateral. These measurements are made once a day only and are immediately telephoned to the watermaster, who enters them on specially prepared record sheets in his office. This record is also sent to the office each day on a card, each ditch tender reporting the measurements in his particular district; that

is, the canal or lateral which he covers, the amount of water he receives in cubic feet per second, the point of measurement, the amount of water passed on to the district below, the amount distributed, and the amount wasted.

3. Measurements at each point of delivery to irrigators.—The record of these measurements is sent in daily on a daily report card which shows the name of each user to whom water is supplied, the time it was turned in to him, the time it was shut off, the amount delivered in cubic feet per second and in acre-feet. The latter amount is computed in the office of the watermaster.

The structures on the Truckee-Carson project were designed with the idea of delivering water to all laterals and to farmers over ordinary flashboard gates, and the plan of measurement adopted has necessarily had to conform to them. Rule No. 9 of the instructions to operation employees already referred to covers the matter of measurement as follows:

9. Measurements of water.—The measurement of water passing through the irrigation canals of the Truckee-Carson project is an important duty of the ditch and gate tenders. The amount of water delivered to each farm should be accurately known in order to determine how much water is being used. The water rights sold by the Reclamation Service will call for a definite amount of water per acre of land, the water to be measured at the turnout to the farm.

For the convenience of the ditch tenders the following set of tables have been calculated, in order that the proper measurements can be made under the various conditions existing.

Four different kinds of measurement are likely to be made:

(*a*) Measurement of water over weir when curtain of water falls free.

(*b*) Measurement of water through opening under pressure, the water falling free below.

(*c*) Measurement of water through opening under pressure, the opening being submerged.

(*d*) Measurement of water over weir submerged.

While it is not possible to make accurate measurements through or over the flashboards under the conditions present, the results are amply satisfactory while water is plentiful. The engineer finds that he gets the best results by measuring through submerged openings or openings under pressure, and follows this plan wherever possible.

RECORDS.

The records of the water measurements made are no more complete than the records of water delivery kept in the office of the watermaster at Fallon. The watermaster keeps a log book, into which he enters all telephonic reports of gate tenders and ditch tenders. He also receives, checks, and files the daily reports of the ditch tenders, showing the amount of water received, delivered, wasted, and passed on by them, as well as the daily reports of all of the water distributed to irrigators. From these he makes up a journal, showing the amount of water delivered to each irrigator each day of the month, the total amount distributed, the total amount wasted, the " invisible loss," the water passed on, the total water accounted for, and the total received.

The last two items show the extent of the inaccuracy in the measurements. The invisible loss is intended to cover seepage and evaporation losses and the inaccuracies in measurement. Each sheet in the journal is sufficient to show the total deliveries by one ditch tender for one month, by which it is possible to determine at the end of the year the approximate amount of water each irrigator has received. The record is valuable both for settling controversies with irrigators and for showing the approximate duty of water on the project, and although daily report cards are kept this journal is the complete working record of the office, and great care is taken to make it complete and accurate.

It was not practicable to ascertain the exact cost of water delivery on this project. The force concerned with water delivery is charged also with the duty of keeping careful watch of the system, maintaining an unobstructed flow in the canals and laterals, attending to all ordinary repairs of ditch banks and telephone lines, killing gophers and muskrats, taking the agricultural census, and making homestead applications. These operations cost approximately $18,000 in 1908, which amount included a portion of the salary of the project engineer, but nothing for the large force employed in the maintenance of the canal, and is of little value as a basis for comparison with the cost of delivery on other systems because of the extraordinary conditions found on a large project during the first years of its settlement. In 1908 the annual maintenance charge was 40 cents per acre, but this has proved insufficient and an increase to about 60 cents is being contemplated. This amount is charged for every acre settled whether irrigated or not, beginning with entry on the land or with formal application for water by owners of private lands.

REVIEW AND SUMMARY.

The foregoing descriptions of the plans of delivery should offer many helpful suggestions to the canal manager who has before him the task of arranging or improving a system of water delivery. No discussion of water delivery can be complete that does not consider all canals, because there is hardly a canal that does not have interesting differences from other canals, due largely to differences in the ways men do the same or similar things. It seems possible to outline with some authority certain established principles of delivery that might be followed profitably wholly or in part on most canals, and this is attempted in the following pages.

PLANS OF DELIVERY.

A canal manager has the choice of three general plans, and his choice determines largely his success. Although he should not overlook local conditions and needs, he can not afford to be too strongly influenced by them and fail to profit by experience elsewhere.

DELIVERY OF CONTINUOUS FLOW.

This plan was adopted at first on a very large majority of the canals in this country, outside of Utah and southern California, and is still used on some canals in nearly every Western State and on most of those in Montana, Wyoming, and other sections situated similarly as to crops, season, water supply, and size of individual holdings. Where the water supply is abundant and the farms as large as 160 acres this plan may give fairly satisfactory results because of the size of stream ordinarily allotted to such an area planted to general crops—say 2 cubic feet per second, which is sufficient to constitute an economical irrigating head. However, where the water supply is restricted, as is the case in nearly every irrigated section in this country, and the farms are small and intensively cultivated, delivery in continuous flow is utterly unsatisfactory from every standpoint. It is wasteful of time and of water, conducive to lax methods of both irrigation and farming, and wholly antagonistic to any system. A notable exception to this is the Sunnyside Canal in Washington, where the use of small irrigation heads run in small furrows is desirable owing to the rolling land and the texture of the soil. Delivery in continuous flow from this canal has been well developed and is attended with the best results, yet it is to be noted that the manager is looking forward to modifying the plan.

DELIVERY IN TURNS OR ROTATION.

In its simplest form this plan of delivery had its origin among the cooperative Mormon communities of Utah, where the water flowing in a ditch or canal was prorated originally on the basis of the acreage irrigated, each acre receiving the entire stream carried or some definite proportion of it for some agreed period of time. With the modifications made necessary by the more complex conditions of larger canals and more diversified products, this is the most generally accepted, and in nearly every way the most satisfactory, plan now in use. It is practiced throughout Utah, wholly or in part on the best canals of Colorado and California, almost entirely in Arizona and New Mexico, on some of the best canals in Idaho, and in fact on all canals, with few exceptions, where any pretense is made to follow the best practice. The exceptions are such canals as the North Poudre and the Consolidated Home Supply in Colorado, the Riverside Water Company's canal in California, and the Northern Canal, in New Mexico, on each of which water is delivered practically on demand up to the limit of the total seasonal supply.

The essential feature of rotation is its economy. The greatest waste in irrigation comes from dribbling through farm laterals and over parched fields streams too small to accomplish much more than moistening the bare surface or equaling the rapid evaporation that occurs under usual field conditions. Heavy unavoidable losses attend attempts to supply all portions of an extensive system with water at the same time. The use of larger heads run for only a portion of the time in one section of the main canal or in one or two of the main laterals, to be run in the other sections or laterals later, does away with losses, lessens the time and the help necessary, and gives far better results to the farmers.

Rotation reduces evaporation and seepage losses in the main canals and laterals by increasing the head and the consequent rate of flow and economizes the time of the irrigators in applying water. It encourages care and promptness in application by the certainty that the supply will cease at a stated time whether or not the field is covered, eliminates the waste of a continuous flow when not in use, and aids greatly in the systematic use and delivery of water. The farmers could not be taught to irrigate under any possible plan of continuous flow with such care and regularity as is done under the carefully arranged schedules under which water is delivered by the East Riverside, the Redlands, and other irrigation systems of southern California, or by the Bear River Canal in Utah. If these schedules are maintained, and they are usually, the farmers feel that they will receive their respective proportions at their regular turns and can make their irrigation plans with definiteness. When definite schedules are followed the work of arranging for irrigators to receive water, or for keeping account of the amounts used, is either wholly eliminated or reduced to a minimum. Another point in favor of rotation is that it gives to the owner of 10 acres an equal opportunity with the owner of 50 acres to secure economical irrigation. Under a system of continuous flow the former, with a stream of about 10 inches, would no doubt be required to spend as many days irrigating his field as the latter, with 50 inches, would take to cover five times that area.

DELIVERY ON DEMAND OR APPLICATION.

This is the plan of delivery on four of the most interesting systems described in this bulletin—the Riverside Water Company, at Riverside, Cal., the North Poudre and the Consolidated Home Supply canals in Colorado, and the Northern Canal in New Mexico; also on the Truckee-Carson project in Nevada, although on the last merely as a means of transition to a plan of rotation probably to be adopted after closer settlement of the project. This system can be used with advantage where reservoirs are the chief source of supply and the total available supply for the season may be closely estimated and where the land under irrigation is closely settled. The water can be measured as easily and withdrawn as readily by the farmers to whom it is credited as a bank account. They can make their irrigation plans with certainty, knowing in advance how many acres of sugar beets or potatoes can be carried through the dry summer months, and can withhold water from one crop to apply it to another in such manner as to give the best possible results.

THE DELIVERY FORCE.

The force required to attend properly to water delivery depends on the size of the system, the crops to be irrigated, and the plan of delivery adopted. Water is delivered to 12,000 acres, owned by 520 farmers, under the Davis and Weber Counties Canal in Utah, by a force of 4 men, at an annual cost of 10 cents per acre. On the Farmers' Canal in Montana 60 irrigators water 15,000 acres, and there is connected with water delivery, besides the president of the company, who exercises general oversight, only 1 canal walker, employed for two months each year. On the other hand, while less than 9,000 acres is irrigated under the Gage Canal in California, there are employed for water delivery a chief engineer, 2 head zanjeros or ditch tenders, 3 assistant zanjeros, and 3 laborers, besides a superintendent of water sources and 4 men to watch and care for pumping plants, 1 carpenter, 2 men to repair pipe lines, and 6 men to clean the canal; these last-mentioned, however, are not directly connected with actual delivery. This difference in the forces employed on these canals is due to the different plans of delivery followed and the different requirements. In one case water is delivered in continuous flow to holdings averaging 250 acres planted to general farm crops; in the other it is delivered under a modified plan of rotation to highly cultivated citrus groves. The force employed should be intelligent, well trained, tactful, patient, and industrious. On community systems where one of the farmers is chosen for the work, it is almost impossible to avoid claims of partiality and unfairness on the part of the selfish and less scrupulous irrigators. On the larger canals an experienced engineer or manager is needed to exercise general oversight, with a head watermaster or superintendent under him, who spends his entire time in the field coming personally in contact with the water users and directing in detail the work of the ditch tenders or zanjeros. A few large systems make the serious mistake of trying to get along without the head watermaster, expecting the engineer not only to maintain the canal and keep a water supply in it, but also to direct all of the details of delivery; no system has yet made a success of such an attempt, however, and the few systems on which it has been tried are comparatively new.

A good corps of ditch tenders or zanjeros is another essential, as it is through these men that a canal management comes into contact with the irrigators, and this point of contact is either a source of friction or the direct means of good service. An irrigator expects his share of water when his turn arrives and to have his "head" maintained throughout his turn, and he is naturally dissatisfied if deprived of either. Unfortunately, some irrigators are not averse to appropriating a portion of their neighbor's supply when just a little more will mean saving a valuable crop, and some are suspicious that the ditch tender is dishonest, or that the home districts of some of the directors are being favored at the expense of some less influential persons. To allay such suspicions and to prevent irregularities a ditch tender must be firm and tactful. The best ditch tender is a man who has been an irrigator himself and can appreciate what it means to lose a year's work by failure to get water through another's fault. If measurements are made the ditch tender should be familiar with the units and the simple methods of measurement, and if records of delivery are kept and a regular system followed he must be methodical in his habits and amenable to direction. The Reclamation Service exacts the strictest compliance to its rules by the ditch tenders. On large, private systems the ditch tenders are expected to be ever alert to the interests both of the water users and the company or other organization representing the ownership of the system. Although in controversies good ditch tenders are more likely to be right than the users, yet they are liable to make mistakes, and water users should be prepared to overlook mistakes. Experience is as much a requisite of a good ditch tender as tact, and his pay should be increased with service.

RULES AND REGULATIONS.

Printed rules and regulations, no matter how simple, are desirable helps in water delivery. They are a definite guide and source of authority to ditch tenders as well as a source of information to water users. On some canals rules are made to cover nearly every phase of delivery, on others they contain only general principles, and in incorporated companies they are frequently embodied in the by-laws. It is not practicable to prepare a set of rules that will be applicable to all conditions, but suggestive points can be brought out.

Plan of delivery.—The plan of water delivery actually in force should be stated plainly, so there can be no question concerning it in the minds of the ditch tenders or the irrigators. An impractical plan is frequently outlined in the rules and a different plan followed, which leads to confusion in the minds of the water users and is likely to cause friction between them and the ditch tenders.

Amount of water allowed.—A rule should be included stating the quantity to which each user is entitled, whether a pro rata of the entire supply, a continuous flow of a certain number of inches per acre, or a definite quantity, as a certain number of acre-feet or 24-hour inches per annum. This rule is included often in the rule governing the plan of delivery.

Duties and powers of superintendent and ditch tenders.—A statement of the duties of these employees should be kept constantly before them and the irrigators, and it is well to have a rule covering these points. The duties of such officers and employees can be defined only in general, as they are meeting emergencies constantly for which there is no precedent. It should be made clear that meddling with headgates will not be tolerated, and that infractions of such a rule will be sufficient ground for shutting off the water supply of the guilty irrigator, either until a fine is paid or until the next turn comes. It may also increase the zeal and efficiency of the less faithful ditch tenders, provided such a rule is in force, if every irrigator knows that the ditch tenders are required to make regular trips over their beats to attend to delivery and to be available for messages from the irrigators.

Applications for water and notices of its delivery.—Most systems require the irrigators to make application for water, sometimes regardless of whether or not a definite delivery schedule is followed. The application is required often to be in writing and to be filed at least three days before delivery. Printed blanks in convenient form should be furnished where written application is required.

Obstructions in canals and rights of way.—It is customary to have a rule prohibiting obstructions of any kind to be placed in the canal or rights of way, except on written permission from the superintendent, and then proper passageways for ditch tenders must be provided.

Waste of water.—There should be a rule prohibiting the waste of water, under penalty of having the supply shut off or reduced by the amount of the waste.

Complaints.—Some systems require all complaints from irrigators to be made in writing within a specified time, say, five days, after the act or negligence complained of has been committed.

Units and methods of measurement.—The unit or units of measurement to be used are important and need to be defined clearly. It is important also that the rules specify and describe the methods of measurement to be followed. These should be understood thoroughly by the ditch tenders, who should be proficient in their use, and should have essential tables furnished them.

Water charges.—Where regular charges for water are made, the rates should be included in the book of rules, as the farmers like to have such data in an available and compact form.

Who are entitled to receive water.—Limitations are frequently placed on those who may receive water, such as ownership of stock, ownership of preferred rights, payment of assessments, and similar conditions, and these limitations should be included in the rules.

RECORDS.

Just as order and system are a part of any commercial, mercantile, or manufacturing business of any consequence, so should they be a part of every well-managed irrigation enterprise. Essential facts regarding operations are as much a matter of record in the one case as in the other, as may be seen from the orderly collection and recording of delivery records kept up by such systems as the Sunnyside, the Larimer County, and the Gage canals. The value of operating data as a basis of successful organization and profitable output is likely to be greater than in the case of a commercial or mercantile concern, because in an irrigation enterprise the same investment of capital will involve interests of greater magnitude and affect more incomes than it will in the commercial or mercantile concern, excepting possibly railroad transportation. The keeping of records on many canals would greatly encourage economy in the use of water among irrigators, lessen the friction between them and the ditch tenders, and lighten the labors of the management.

Records of flow.—Most systems that make any pretense to careful use of water keep daily records of the amount taken into the canal, which is very necessary where several receive their supplies from the same source and especially where water is distributed to the canals under public supervision, as in Colorado, Wyoming, and sections of Utah, Nevada, and some other States. Entirely apart from the value of a record of flow in an irrigation canal or pipe line as a means of establishing and maintaining stream priorities, such a record shows from year to year what can be expected, the extent of enlargement required, or the amount by which the duty of water must be increased if the irrigated area is to be extended, and the extent of waste resulting from bad irrigation practice. Its greatest value, however, is as a basis of delivery to the irrigators, to replace the approximating and estimating now so common. Records of flow in main laterals are not kept ordinarily, but would probably be valuable on systems where each main lateral is a distinct delivery district.

Records of delivery to individual consumers.—Whenever that stage is reached in the life of an irrigation enterprise when the use of water begins to crowd the available supply, it is of great importance that measurements be made and records kept of the water delivered to individual consumers. The importance of this is not always recognized, as on many large systems such records are not kept, although they would much more than repay the cost of keeping them. Much progress has been made in this matter, however, during the past ten years, brought about largely by changing the basis of delivery and water charges. Capitalistic or corporation canals formerly charged flat acre rates for water, but this plan has been giving way to that of charging for the water actually delivered, which makes delivery measurements and records essential. Either definite delivery schedules are followed, making records of delivery unnecessary, or such records are kept on 19 of the 30 systems, and to a certain extent on several others described in the first part of this bulletin.

FORMS USED AND SUGGESTED.

In describing the various delivery systems detailed reference was made to the record forms in use and copies were given where practicable. These can be made more suggestive, perhaps, by further description.

Record of flow in main canals or laterals.—This form is simple, and practically the same one can be used on all systems. It merely requires spaces for the name of the channel; the point of measurement; the daily gage readings, with the time taken; and the flow as expressed in the unit of measurement used. It is made in convenient book form, or may be prepared for loose-leaf binding, as indicated, or for a card-filing system. Ordinarily the permanent copy would be made out from daily or weekly field reports by ditch tenders. A suggested form is given below:

Form suggested for permanent record of flow in main canals or laterals.

[This margin for binding.]

NAME OF CANAL.

Monthly record of flow in..
at.. for month of.............................., 19...
Measurements made by ....

Date.	Time.	Gage reading.		Flow in cubic feet per second.	
		Feet.	Tenths.		
1............	....	....	....	....	....
2............	....	....	....	....	....
3............	....	....	....	....	....
4............	....	....	....	....	....
Etc., to 31 ...	....	....	....	....	....

Record of flow in canals and main laterals at all points.—It may be desirable on large systems to keep a record of all measurements made on the main canal and main laterals, exclusive of measurements directly to consumers. Such a record is kept on the Sunnyside and the

Truckee-Carson projects and is found to be extremely valuable, and might be used with profit on all systems where the flow in both the main canal and the main laterals is measured. The sheet required for such a record is necessarily large, 16 by 34 inches being the size used on the Sunnyside project. If the sheets are bound in book form the size of the book may be reduced by having the form cover opposite pages. The form in use on the Sunnyside project is suggested here, arranged for loose-leaf binding. It can be filled out only from daily or weekly reports from ditch tenders, being too bulky for field use. A suggested form is shown below:

Form suggested for permanent record of flow at all points of measurement on main canals and laterals.

[Size 16 inches by 34 inches.]

[This margin for binding.]

NAME OF CANAL.

Daily record of flow in main canal and laterals for month of ...., 190..

Main canal.

Points of measurement.	1		2		3		4		30		31		Average for month.	Total for month.
													Cubic feet per second.	Vertical depth in feet.
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Laterals.

Laterals and points of measurement.	Areas irrigated, in acres.	1		2		3		4		30		31		Average for month.	Total for month.
														Cubic feet per second.	Vertical depth in feet.
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals, cu. ft. sec	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lost or not diverted, cubic feet per second..................		....	....	....	....	....	....	....	....	....	....	....	....	....	....

Daily or weekly reports of flow in ditches.—Perhaps the most convenient shape for weekly reports of flow in main canals or laterals is a card the size of a postal card, with the form printed on one side, similar to those used by the United States Department of Agriculture, the United States Geological Survey, and some canals. Daily reports are seldom made except by telephone, but a similar form would of course answer for them also. A suggested form for keeping such reports follows:

Form suggested for weekly report of flow of water in main canals or laterals.

NAME OF CANAL.

Report of water in ____________ at ______ for week ending ______, 1909.

Day.	Month.	Date.	Time.	Gage reading.		Flow cu. ft. sec.	Remarks.
				Feet.	Tenths.		
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

(Under "Remarks" mention any unusual condition, as "flood," "break in canal," etc., and state how long water was out of canal and when, if at all. Forward this card promptly at end of week.)

——— ——— *Ditch Tender.*

Ditch tender's diary.—These diaries are not as a rule kept in a form to make them useful, although they are very valuable on some systems. In some cases permanent records are made from scratch notes sent to the canal office, but the scratch book is not kept. The value of these diaries has been determined frequently only when rights have been contested, and there are many instances where a properly kept diary would have satisfactorily settled serious disputes.

An admirable diary is being kept by each patrolman on the Sunnyside Canal and filed carefully in the office at Zillah at the end of the season. It is 5 by 9 inches and contains 232 pages. It is made for use during any season, the pages not being dated, space being provided for the month, day, and year. The binding is of stiff board and canvas to insure preservation. The records of flow in the canals or laterals are not entered in this, but a card 4 by 8 inches to take these records is made to slip under small straps at each of the four corners of the inside front cover. Each card covers one week and they are filled out by the patrolmen as they pass over their beats and at the end of the week sent to the office at Zillah for filing. The points of measurement, with the size of the weir at each, are noted in the left-hand column, seven columns being provided at the right for entering the flow of each day of the week.

Records of delivery to irrigators.—A great variety of forms are in use for keeping records of such delivery to irrigators because of the many conditions under which water is delivered. They include cards, sheets, and books of different forms. One of the simplest card forms is that used on the Truckee-Carson project, of which a copy is reproduced below. This card is filled out and sent daily to the project headquarters at Fallon. By using both sides of all of the lines, a record of 40 deliveries can be entered on it.

Form of record of water delivery to irrigators used on Truckee-Carson project, Nevada.

RECORD OF WATER DISTRIBUTED.

Month ------.   Date ------, 19--.

User's name.	From (time)—	To (time)—	Second-feet.	Acre-feet.

...., *Ditch Tender.*

By adding to the above form the crops irrigated, it might be adapted to another system; by eliminating the columns for the quantity of water delivered it would suit a system on which devices for measurement to irrigators have not yet been provided. In using this form the ditch tenders on the Truckee-Carson project designate the hours by 1 to 24, 1 being 1 a. m. and 24 being 12 midnight, thus doing away with the confusion of morning or afternoon.

Books for entering records of individual deliveries are provided on the North Poudre, the Larimer County, the Consolidated Home Supply, the Santa Ana Valley, and the Bear River canals, in addition to the Sunnyside Canal, the various forms of which have been described. The best books for this purpose are of a size to be carried conveniently in the pocket, substantially bound in boards and canvas, and containing the proper columns and headings. The loose-leaf book used on the Bear River Canal is more of a guide to the ditch tenders than a book in which to enter deliveries, as delivery is made according to a definite schedule made up by the chief engineer. For such purpose the loose leaves are convenient on account of the ease with which changes can be entered. For a book to be filled out and kept throughout the season by the ditch tenders the bound book is preferable, because the only valuable record in case of dispute is the original record made by the ditch tenders at the time of delivery, but where the original record is sent to the office as soon as taken, or weekly, or monthly, a book or pad with detachable leaves punched for filing in binders is perhaps the best that can be used. A leaf from such a book, used on one of the California canals, is shown below. Probably no more convenient and compact device could be arranged.

Detachable loose-leaf form for keeping record of deliveries to irrigators on a California canal.

[Space for binding.]

Report of irrigation from......Canal......Div......Co.
Water ordered by...... ....
For account of...... ....
Land irrigated.... | T.... | R.... | Sec........ | Lots............ | Acres............

From gate.	Water turned on.			Water turned off.			Hours flow.	Measurements of openings.			
	Date, 190–.		Hour.	Date.		Hour.		Upper.	Lower.	Depth.	Width.
....	....	....	.... m.	....	....	.... m.	....	....	....	....	....
....	....	....	.... m.	....	....	.... m.	....	....	....	....	....
....	....	....	.... m.	....	....	.... m.	....	....	....	....	....
....	....	....	.... m.	....	....	.... m.	....	....	....	....	....

Crop......Soil......Distance from canal......
Condition of delivery ditch...... ...., *Zanjero.*

[Indorsement on back.]

ENGINEER'S MEMORANDUM.

This delivery reduced to terms of second-feet flowing per twenty-four hours.

Total delivery, ______ second-feet.
Average per acre, $______
Total per acre, $______ second-feet, $______
Average per acre, $______

Below are the forms used by the Imperial Water Company No. 5, in Imperial Valley, Cal., for recording individual deliveries, and the form of receipts for water delivered used by the Modesto and Turlock Irrigation districts. The latter are not filed in order, the stubs being preserved, as bound, for use in case of dispute.

Form for keeping record of deliveries to irrigators used by Imperial Water Company No. 5 in California.

IMPERIAL WATER CO. NO. 5.

Delivered to —

Owner ______ ______
Tenant ______ ______
Cert. No. ____. On ______ Sec. ____ Twp. ____ S., R. ____ E. S. B. M.
Month ______ ______ Lateral.

Date.	Hour.		Front measurement.	Back measurement.	Depth of opening.	Width of opening.	Over pour measurement.		Second-feet.	Amount.
	Turned on.	Turned off.					Depth.	Width.		
....	....	....	....	....	....	....	....	....	....	$........
....	....	....	....	....	....	....	....	....	....	$........
....	....	....	....	....	....	....	....	....	....	$........
....	....	....	....	....	....	....	....	....	....	$........
....	....	....	....	....	....	....	....	....	....	$........

Total No. hours ____
Received by ______ ______
Delivered by ______ ______

Form of water receipt filled out by ditch tenders and signed by irrigators on the Modesto irrigation district, in California.

WATER RECEIPT.

Lat. No. ...... Diverting gate No. ......
Water received:
Date ....
Number of hours ....
Acreage ....
Crop ....
Water refused on ....
Date of offer ....
Reason of refusal ....
...., *Ditch Tender.* ...., *Irrigator.*

WATER RECEIPT.

Lat. No. ...... Diverting gate No. ......
Water received:
Date ....
Number of hours ....
Acreage ....
Crop ....
Water refused on ....
Date of offer ....
Reason of refusal ....
...., *Ditch Tender.* ...., *Irrigator.*

Form of water receipt filled out by ditch tenders and signed by irrigators on the Turlock irrigation district, in California.

WATER RECEIPT.

Lat. No.... Diverting Gate No....
Water received:
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Water refused on......
Date of offer......
Reason of refusal............
...., *Irrigator.*
...., *Ditch Tender.*

WATER RECEIPT.

Lat. No.... Diverting Gate No....
Water Received:
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Date.... Hours.... Acres.... Crop....
Water refused on......
Date of offer......
Reason of refusal............
...., *Ditch Tender.*
...., *Irrigator.*

Water ledgers.—The use of water ledgers or other books for entering records of seasonal or monthly deliveries is a feature of the record keeping on some systems. On the North Poudre, Gage, Consolidated Home Supply, and the Northern canals, and the Truckee-Carson and Sunnyside projects ledgers of various kinds are kept, as hertofore described.

WATER CHARGES.

The amount of water used rather than the number of acres irrigated is now established thoroughly as the wisest and best basis for charging for water. In cooperative or mutual companies such a question does not arise ordinarily, as stock ownership entitles an irrigator to his share of the supply run. Where water is sold to irrigators the question is an important one. Charging for the number of acres irrigated has proved wasteful both to consumers and irrigation companies and unjust to the careful irrigator by requiring him to pay the same amount for the water he uses as his slovenly neighbor pays for twice that amount. Paying for water actually received, and therefore at the same rate for water wasted as for water used, has been found not only to reduce the total amount consumed but also to benefit greatly the land irrigated. It also increases the areas possible to irrigate, benefiting both the individual irrigators and the public. It is unfortunate that this improved irrigation practice can not be applied to the hundreds of irrigation systems on which water is not sold to the irrigators. The same result might be attained, in a measure, by basing maintenance and operation assessments in cooperative and mutual companies on the water used rather than on the shares of stock owned, as is done on the small canals on Hood River in Oregon, provided such an arrangement could be made legal. A very convenient method of computing water charges is in use by the Imperial Water Company No. 1, at Imperial, Cal. Under this system the charge is 50 cents per acre-foot, and as 2 acre-feet of water is practically equivalent to 1 cubic foot per second running for twenty-four hours (1.9834 acre-feet), amounts to $1 per cubic foot per second for each twenty-four hours. The flow through a measuring box, expressed in cubic feet per second, becomes therefore the charge for the water by pointing off two decimal places. To render computations in the field unnecessary, tables have been prepared and printed which show at a glance what the charge is under all conditions of measurement. Measurements are made over weirs and through submerged orifices under pressure, and the tables in use apply to weirs up to 48 inches long with a depth over the crest up to 10 inches and to submerged orifices up to the same length and depth, with pressures of 1.5 to 14 inches.

Below is shown a copy of the table used for submerged orifices with a pressure of 6 inches. The left-hand vertical column indicates the height and the top horizontal column the length of the orifice. If the height of the orifice is 5 inches and the length 36 inches, the charge is found in the column headed 36 and to the right of 5, which is $4.41:

Table used for computing charge for water through orifices under 6-inch pressure on Imperial Canal No. 1.

Height of the orifice in inches.	Length of orifice in inches.														
	30.	32.	33.	34.	35.	35½.	36.	37.	38.	39.	40.	42.	44.	46.	48.
1	73	78	81	83	86	87	88	91	93	96	98	103	108	113	118
1½	110	118	121	125	129	130	132	136	140	143	147	154	162	169	176
2	147	157	162	167	171	173	176	181	186	191	196	206	216	225	235
2½	184	196	202	208	214	217	220	227	233	239	245	257	269	282	294
3	220	235	243	250	257	261	265	272	279	287	294	309	323	338	353
3½	257	274	283	292	300	304	309	317	326	334	343	360	377	394	412
4	294	314	323	333	343	348	353	363	372	382	392	412	431	451	470
4½	321	353	364	375	386	391	397	408	419	430	441	463	485	507	529
5	367	392	404	416	429	435	441	453	465	478	490	514	539	563	588
5½	404	431	445	458	472	478	485	499	512	526	539	566	593	620	647
6	441	470	485	500	514	521	529	544	559	573	588	617	647	676	706
6½	478	510	526	541	558	565	573	589	605	621	637	667	701	733	764
7	514	549	566	583	600	608	617	635	652	669	686	720	755	789	823
7½	551	588	606	625	643	652	661	680	698	716	735	772	808	845	882
8	588	627	647	666	686	696	706	725	745	764	784	823	862	902	940
8½	625	666	687	708	729	739	750	771	791	812	833	875	916	958	1,000
9	661	706	728	750	772	783	794	816	838	860	882	926	970	1,014	1,058
9½	698	745	768	791	815	826	838	861	884	908	931	978	1,024	1,071	1,117
10	735	784	808	833	857	868	882	906	931	955	980	1,029	1,078	1,127	1,176

COST OF WATER DELIVERY.

Below are given copies of two tables summarizing the cost of water delivery on some of the typical systems described. The first table relates to canals or companies for which the delivery costs obtained include deliveries to individuals; the second one relates to systems for which the delivery costs include delivery to laterals only, delivery on the laterals being left to the irrigators. In the former case the average annual cost per acre is 41½ cents; in the latter case it is only 7½ cents. The larger costs on some of the California systems in the first table are due to the larger number of irrigators and the smaller holdings under them, the latter averaging under 8 acres on the Redlands system, while the average holding on the Consolidated Home Supply Canal is nearly 154 acres. In the second table the low cost on the Farmers' Canal results from the short irrigation season of only two months and from the facts that the crops grown are principally grain, clover, and alfalfa, and that the average holding is 250 acres.

Annual cost of water delivery per acre on 13 typical systems where cost includes delivery to individuals.

Company or system.	Cost per acre.
Gage Canal Company, California	$0.54
East Riverside Water Company, California	.95
Riverside Water Company, California	.73
Redlands Water Company, California	1.30
Azusa Irrigating Company, California	.48
Modesto Irrigation District, California	.40
North Poudre Canal, Colorado	.16
Consolidated Home Supply Canal, Colorado	.15
Bear River Canal, Utah	.16
South Jordan Canal, Utah	.15
Utah and Salt Lake Canal, Utah	.09
Northern Canal, New Mexico	.15
Tempe Canal, Arizona	.14
Average	.41½

Annual cost of water delivery per acre on 4 typical canals where cost includes delivery to the laterals only.

Company or system.	Cost per acre.
Rockyford Canal, Colorado	$0.08
Wheatland Canal, Wyoming	.11
Farmers' Canal, Montana	.01½
Davis and Weber Counties Canal, Utah	.10
Average	.07½

LATERAL ORGANIZATIONS.

A question arising in the consideration of the plan of water delivery for some irrigation systems is the separate organization of those receiving water from the same lateral, which is often desirable because of the resulting economy and simplicity of management. Irrigators like to be in close touch with the one in charge of distributing water to them, and there is always dissatisfaction when they are not. On large systems the superintendent is likely to be so busy that he seldom gets away from the main canal or the main laterals, leaving the ditch tenders to adjust possible differences with or between the irrigators on the laterals. The farmers would get along better sometimes if they chose and directed their lateral ditch tenders themselves, as is done on small systems in Utah and elsewhere, as on the South Jordan and the Utah and Salt Lake canals. Again, the affairs of the system might run more smoothly if the duties of the engineer or superintendent end with maintaining the flow in the main canal and in distributing to each lateral its share of the total supply, as is the plan on the Larimer County Canal and numerous other canals in the irrigated sections. On these canals, however, the irrigators on the same laterals are merely working under a general understanding among themselves that one of their number shall see that each receives his proper turn and proper share. On a lateral with 50 or 100 irrigators, however, either a closer agreement is necessary or the company superintendent must have charge. Separate lateral organizations, each with its own directors and ditch riders and treasury, are maintained on the Wheatland Canal, and all business with the laterals, both in maintenance and operation, is transacted by their respective organizations, independently of the main canal company. The general superintendent of the latter is called in only to aid in the settlement of disputes. Contrary to the idea of separate lateral organizations, in the Modesto irrigation district the large private laterals, built to open particular tracts of land and until recently managed independently of the district, have now been taken over by the district at the request of the irrigators, as it is believed that the water will be divided more satisfactorily by the district. On the other hand, the managers of the two Reclamation Service projects already described are looking forward to the time when the users on the separate laterals will be organized for water distribution, and the manager on the Sunnyside project is experimenting already with that end in view.

So far as is known, the most complete lateral organizations thus far effected are those on the Amity Canal in Colorado, which were incorporated separately under the laws of that State. The average acreage under these nine laterals is 2,000 acres. The laterals were built by the Amity Canal Company but were transferred for purposes of maintenance and management to lateral organizations as soon as three settlers had taken up holdings and begun to irrigate, the company retaining the unassigned rights in the laterals pending settlement of the areas under them. This plan of organization is somewhat similar to that of the canals in the Imperial Valley in California, where the California Development Company, pending settlement, controls unsold stock of the different water companies, which are virtually organizations of the large laterals of a larger system. Very complete and efficient lateral organizations are also in operation on canals around Fresno, Cal.

Lateral organizations having complete charge of water delivery are not practicable where water is measured and sold to users at a definite quantity rate, except on very large systems. Under such conditions there must be some definite authority in control, as there must be a single system of delivery and charges, applied everywhere alike. Where water is prorated and charges assessed annually, however, and the system is too large to enable the superintendent or other officer in charge to supervise delivery personally, such organizations are of much value. They make prorating more easy, increase the interest of the irrigators in the management of the system, thus lessening their antagonism. They lighten the duties of the superintendent and at the same time increase his efficiency in making proper divisions between the laterals and in maintaining the main channels free from breaks and obstructions.

MEASUREMENT OF WATER.

Records of the amount of water delivered to individual consumers become of importance as soon as the use of water begins to crowd the available supply, so that it becomes necessary to limit each irrigator to the amount called for by his contract or his right in the canal. This can be done only by measuring the water run to laterals, on which the flow is prorated on a time basis, or by measuring the water run to individual consumers, and the working out of the practical details of water measurement is one of the most difficult questions of water delivery. Many canals irrigate land nearly as high as the top of the water running in them, making the fall or head so little that the use of measuring devices is impossible. In other canals, where there is sufficient fall or head to use measuring devices, there is often so much fluctuation in the flow that even approximate accuracy can be obtained only by frequent readings of the measuring device or by the use of automatic registers. The latter are impracticable for use on farm laterals, however, because of their cost and the attention and care necessary to keep them working accurately. In an effort to overcome both of these difficulties several engineers are experimenting with original water meters, designed to measure accurately under varying heads with a minimum loss of head, to be capable of direct reading in a definite unit of quantity, and to be constructed and installed at a cost within the reach of irrigators. Until some such device is perfected and made available irrigators must get along with the more or less unsatisfactory devices now in use. Technical descriptions of these may be found in various bulletins, published by this Office and the different agricultural experiment stations, as well as in books on irrigation engineering.[a] It might be stated here, however, that when the fall will permit, the Cipolletti weir is one of the most satisfactory devices known. As stated in the description of the Sunnyside project, the device is specially valuable where the fluctuation in the canal flow is not great. When the fall is very small and the fluctuation considerable, some form of submerged orifice is most desirable, as it will measure with the least loss of head and with the least inaccuracy under changing head of any device in use.

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[a] Colorado Sta. Bul. 27; Montana Sta. Buls. 34 and 72; Wyoming Sta. Bul. 53; "Special Instructions to Watermasters," state engineer Utah, 1898; U. S. Dept. Agr., Office Expt. Stas. Bul. 86.

CONCLUSIONS.

The management of irrigation enterprises is one of the most fruitful subjects of inquiry in the whole field of agricultural economy. The public is interested in it through its desire to see the best economic and business principles applied in the use of one of the country's richest resources. The irrigator is interested in it through the close relation it bears, in the case of his own canal, to his own income. Those seeking employment are interested in it because of the field it offers for a profitable and useful livelihood.

Water delivery is the part of irrigation management that comes in closest touch with the man who is using the water, and is therefore the part in which he is most immediately interested. The superintendent and the ditch tender are the ones who bring him his supply of water, and anything that will help them in perfecting and executing their plan of delivery is of direct benefit to him.

This bulletin presents facts regarding water delivery in the different States and Territories to assist in making the application of the best principles more general. While many delivery systems are admirable and show careful regard for order and efficiency, few, if any, of them are entirely satisfactory to their managers or are the best that will be attained. They offer practical suggestions, however, to any irrigation manager who is arranging a plan of delivery. Especially suggestive are the plans and details that have been worked out in the delivery systems of the best canals in southern California; of such canals as the North Poudre, the Larimer County, and the Consolidated Home Supply canals in northern Colorado; of the Bear River Canal in Utah; of the Northern Canal in New Mexico; and of the projects of the Reclamation Service. On most systems the details in force are original with their superintendents or managers rather than copies of details perfected elsewhere. The central ideas however, have been developed in many sections, sometimes independently of the development of the same ideas elsewhere, sometimes as an outgrowth of what others had done.

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